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PRODUCT ENGINEERING

AUGUST, 1952

RAYDAC AUTOMATIC COMPUTER

IN THIS ISSUE—Torque Motors • Overload Relays • Frequencies of Tapered Bars • Twisting and Locking Assemblies • Organic Coatings • Ultrasonics

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U. S. DEPARTMENT OF COMMERCE

NATIONAL PRODUCTION AUTHORITY

TITLE 32A—NATIONAL DEFENSE, APPENDIX

Chapter VI—National Production Authority, Department of Commerce

[NPA Order M–80, Schedule A]

M–80—IRON AND STEEL—ALLOYING MATERIALS AND ALLOY PRODUCTS

SCHEDULE A—NICKEL-BEARING STAINLESS STEEL, HIGH NICKEL ALLOY, AND NICKEL

...ound necessary and ...ote the national de... ...pursuant to the au... ...101 of the Defense ...950, as amended. In ... NPA Order M–80, on ...ule is based, there has ...n with industry repre... ...uding trade association ..., and consideration has ...o their recommendations. ... is issued under NPA Order ... made a part of that order. ...of NPA Order M–80 subjects ...location and prohibits the use ...n nickel-plating in the manu... ...d assembly of certain products.

...ons
... prohibited.
...ons.

contained in that list under the subheading C–I. No person shall use any nickel silver, or any component parts made therefrom, in the production, manufacture, or assembly of any product other than those products contained in that list under subheading A–III, unless prohibited by subheading B–III. No person shall use nickel-bearing stainless steel, high nickel alloy, or nickel silver for decorative or ornamental purposes.

SEC. 3. *Exceptions.* (a) The prohibitions contained in section 2 of this schedule with respect to products included in subheading A–I and A–II of the list at the end of this schedule shall not apply to the use of nickel-bearing stainless steel, high nickel alloy, or nickel silver, or component parts made therefrom, to the extent that any such materials were contained in a person's inventory on March 1, 1951, or had been ordered by that person and such order had been accepted by the producer for February 1951 production and received by that person in his inventory prior to June 1, 1951. This exception is applicable only to the extent that such materials are wholly unsuitable for use in the production, manufacture, or assembly by such person of any product not included in subheading A–I and A–II of that list.

...bitions contained in sec... ...chedule ...

(d) Any unassembled component parts, produced prior to the issuance of or in conformity with, this schedule, of products subject to the provisions of section 2 may be sold any time, and the purchaser thereof may assemble such component parts into products subject to the prohibitions of section 2 of this schedule at any time, provided such component parts are wholly unsuitable for use in the production, manufacture, or assembly of any product not prohibited.

(e) Notwithstanding that a product may be contained in the list under the subheadings A–I, B–I, and C–I, the prohibition contained in section 2 of this schedule shall not apply if any such product is manufactured exclusively for use on board vessels and aircraft operated by the Armed Forces of the United States, including the United States Coast Guard.

SEC. 4. *Records.* Every person who relies on the provisions of paragraphs (a), (b), or (c) of section 3 of this schedule shall prepare a detailed record showing: (a) the quantities of nickel-bearing stainless steel, high nickel alloy, and nickel silver, or component parts made therefrom, which were in his inventory on the first days of each month commencing with December 1950, and ending September 15, 1951, which were wholly unsuitable for use by him in...

IF YOUR PRODUCTION IS THREATENED BY THE CRITICAL MATERIAL CONTROLS

Is your product on this long list prohibited from using critical materials such as nickel-bearing stainless steel? Are you having difficulty obtaining aluminum or copper?

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SHARONSTEEL

VOLUME 23 — PRODUCT ENGINEERING — NUMBER 8

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AUGUST, 1952 — **PRODUCT ENGINEERING** — **Vol. 23, No. 8**

Published monthly by McGraw-Hill Publishing Company, Inc., James H. McGraw (1860-1948), Founder. **Publication Office, 99-129 North Broadway, Albany 1, N. Y.**

Executive, Editorial and Advertising Offices: McGraw-Hill Building, 330 W. 42nd St., New York 36, N. Y. Curtis W. McGraw, President; Willard Chevalier, Executive Vice-President; Joseph A. Gerardi, Vice President and Treasurer; John J. Cooke, Secretary; Paul Montgomery, Senior Vice-President, Publications Division; Ralph B. Smith, Vice-President, Editorial Director; Nelson Bond, Vice-President, Director of Advertising; J. E. Blackburn, Jr., Vice-President, Circulation.

Subscriptions; Product Engineering—Subscription Service, 99-129 N. Broadway, Albany 1, N. Y., or 330 W. 42nd St., New York 36, N. Y. Allow one month for change of address.

Subscriptions are solicited only from executives, engineers and consultants engaged in the design of machinery and other engineered products. Position and company connection must be indicated on subscription orders.

Branch Offices: ATLANTA, R. M. Maultsby, 1321 Rhodes-Haverty Bldg.; BOSTON, M. A. Williamson, Jr., 350 Park Square Bldg.; CHICAGO, Anson E. Meanor, H. M. Higgins, 520 N. Michigan Ave.; CLEVELAND, A. F. Tischer, 1510 Hanna Bldg.; DALLAS, J. H. Cash, First National Bank Bldg.; DETROIT, P. G. Weatherby, 856 Penobscot Bldg.; LOS ANGELES, H. L. Keeler, 1111 Wilshire Blvd.; NEW YORK, J. A. McGraw and D. C. McGraw, Jr., 330 W. 42nd St.; PHILADELPHIA, David G. Jones, Architects Bldg.; PITTSBURGH, A. F. Tischer, 738-9 Oliver Bldg.; SAN FRANCISCO, R. E. Dorland, Jr., 68 Post St.; WASHINGTON, National Press Bldg.; LONDON, McGraw-Hill House, 95 Farringdon St., London E.C. 4, England.

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Single copies 50¢. United States and possessions, $5 for one year, $8 for two years, $10 for three years; Canada, $6 for one year, $10 for two years, $12 for three years; Latin American countries, $15 for one year, $25 for two years, $30 for three years; all other countries $20 for one year, $30 for two years, $40 for three years. Entered as second class matter August 21, 1936, at the Post Office at Albany, N. Y., under act of Mar. 3, 1879. Printed in U. S. A. Copyright 1952 by McGraw-Hill Publishing Co., Inc.—All Rights Reserved.

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Highlights

When requesting further information from companies and organizations mentioned in the items below, confusion can be avoided by referring to the issue of Product Engineering in which items appear

METALLIC MATERIALS

A HIGH-STRENGTH copper-silver material is cold-worked to obtain tensiles ranging from 140,000 to 165,000 psi. Alloy contains 94 percent Cu and 6 percent Ag, is sold only in heat-treated and cold-worked condition, and has electrical conductivity of 70 percent I. A. C. S. Handy and Harmon produces the metal as round or flat wire.

CARBONIZING IS NOT NEEDED when various composite metals are substituted for pure nickel in electron tubes. General Plate Division, Attleboro, Mass. makes strip in the following combinations: Alfer, aluminum alloy clad on both sides with low-carbon steel; Alnifer, low-carbon steel clad with aluminum on one side and nickel on the other; and Nifer, low-carbon steel with nickel on both sides.

ATOMIC ENERGY COMMISSION has placed an $11-million order with Carborundum Metals Co., Inc., a subsidiary of Carborundum Co. of Niagara Falls, for production of zirconium and hafnium metal. The contract is a step in program to encourage private enterprise to take over portions of AEC's work. Zirconium is useful in construction of nuclear reactors because of its low absorption of neutrons and corrosion resistance.

A COERCIVE FORCE of 3,000 oersteds characterizes Bismanol, a new permanently magnetic material developed at the Naval Ordnance Laboratory. This flux density is available in short magnets where the length-to-diameter ratio is one or less. Bismanol magnets are powder pressings so that complicated shapes can be made to close tolerances without requiring additional finishing.

IMPROVED ALLOYS OF GERMANIUM, particularly for use in rectifiers, are the basis of Patent 2,600,997 assigned to the Purdue Research Foundation. These alloys are all of the so-called N-type semi-conductors that combine germanium with Cu, Mg, Zn, Ti, Sn, Cr, Co and nickel.

CONSERVATION OF NICKEL AND CHROMIUM in heat resistant castings is the objective of research sponsored at Battelle Memorial Institute by the Alloy Casting Institute of Mineola, N. Y. From knowledge of the Fe-Cr-Ni alloy system and field experience, casting metallurgists selected an HF-type alloy containing 21 percent Cr and 9 percent Ni as the material most likely to provide the combination of strength and corrosion resistance required for intermediate temperature service, in the range from 900 to 1,400 F, which is critical in many applications.

NONMETALLIC MATERIALS

CORROSION OF SILVER CONTACTS has occasionally been caused by certain chemicals used in phenolic molding compounds. To prevent this attack, Durez has formulated "15528 Black", a general-purpose phenolic with same molding and physical properties as the types commonly used for electrical applications.

SELF-LUBRICATED SURFACES result when Lead-Lube is used in gears and bearings. A high metallic lead content in the form of pulverized lead dust is kept as a permanent suspension in a base grease, so as not to break down until the lead has been deposited as a coating on the wearing surfaces. In older equipment, the metallic lead will resurface pits and scores, and restore a degree of efficiency to worn parts.

TURBO-JET ENGINE OIL, said to be thin but extremely stable, has been developed by Gulf Oil Corp., Pittsburgh 30, Pa. New product will pour at -65 F and lubricate in the 500-F range which is typical of some jet engine bearings.

IMPROVED ELECTRICAL PROPERTIES in alkyd plastics have been achieved in a new thermosetting compound produced by the Plaskon Div., Libbey-Owens-Ford Glass Co., Toledo 6, Ohio. The electrical properties are reported to compare favorably with phenolic and melamine materials.

(continued on page 7)

Look for a 1-Track Mind...

For Results in Thermosetting Moulded Plastics

Your thermosetting jobs are set for a clear right-of-way here at Kurz-Kasch. Compression, transfer and plunger moulding methods are what we are set up for expressly—both physically and mentally. Idea, of course, is to deliver all the advantages of specialization and experience.

You want a moulder strong on tool control and production, too—and that's the second strong part of our system. Matter of fact, we've just finished adding more mould-making capacity to one of the finest toolrooms in the business.

If you have a thermosetting job (any of 'em including Teflon or moulded glass-filled polyesters) that track's pretty clear right now. If, on appraisal, the job you submit can be more effectively handled by other moulding methods, we'll be happy to recommend fellow-specialists in the proper fields. Call us—or one of our offices.

Kurz-Kasch

FOR OVER 36 YEARS PLANNERS AND MOULDERS IN PLASTICS

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A NEW STYROFOAM with greatly reduced burning characteristics, has been developed by Dow Chemical. Said to meet ASTM requirements for a "self-extinghishing" plastic, Styrofoam 33 is expected to find use in the low-temperature insulation field. For purposes of identification, the new material will be tinted blue.

NEW RUBBER-LIKE MATERIAL is being produced in pilot-plant quantities, according to du Pont. Called Hypalon S-2, material is described as completely resistant to ozone and is slated for use in tiretreads and white-sidewall tires, and as a protective coating for weather-stripping in cars. And new blends are always a possibility.

COMPONENTS

A DECALCOMANIA that will adhere to plastic and other special surfaces is announced by the O. Austin Co., Inc., Brooklyn 21, N.Y. Designed for application to surfaces to which ordinary decals will not adhere, Austicals are reported to adhere after ordinary water dip to polystyrene, vinyl, acetate and phenolic, as well as to polished or chrome-plated metals.

SLOWING DOWN TO A FEED of less than 1/300 rev per stroke is easily accomplished by a 3/4 in. dia over-running clutch used as a variable-stroke ratchet. High Precision, Inc., Hamden, Conn., markets the miniature assemblies for use on recording instruments, business machines and servos.

THE FUSISTOR is a circuit element that, under normal electrical load, will operate as a resistor only, but when subjected to an overload of current, will sustain such overload for a pre-determined time. It then melts or burns out before expiration of another given predetermined time, thus functionning as a fuse. The Milwaukee Resistor Co. claims there is no spewing of flame or spark emission when fusion takes place.

A MAGNETIC SWITCH has been developed by Bell Telephone Laboratories which can select the proper telephone circuit in less than three-thousandths of a second while a person dials any number. The new switches are more readily manufactured and adjusted than the current models and have higher operating efficiencies, longer life, and require less power to operate. Life expectancy is one billion operations, equivalent to one switching movement every second for a period of more than 30 years.

INDICATION OF A CHANGE is obvious when it is noted that a rod and wire mill of the Western Electric Co. has turned out more than 40 million feet of aluminum wire for delivery to the telephone companies throughout the country. 18,000 feet of 22-gage cable has also been made. These aluminum wires are pulp insulated, stranded into cable and sheathed with Alpeth, which is a combination of aluminum and polyethylene.

AN AIRCRAFT WIRE designed to resist chemical action of Skydrol, the non-flammable hydraulic fluid, and low temperatures in being marketed by Suprenant Mfg. Co. of Boston, Mass. The wire reportedly meets Specification MIL-W-5274 A, resists oil, grease, fungus, abrasion and flame. It is protected by an extruded primary insulation made from Geon polyvinyl chloride plastic and a nylon outer covering.

MINIATURE WIRE, made in AWG sizes from 30 to 20, has fused-on Teflon insulation designed to provide heat resistance to 250 C and electrical protection against d-c voltages up to about 10,000, The Tensolon material is manufactured by Tensolite Insulated Wire Co., Tarrytown, N.Y.

PROCESSES

BATH CONTAMINATION IS NO PROBLEM when General Motors dip-coats complex steel parts with aluminum to increase corrosion and heat resistance. This is accomplished by using a steel shell lined with an inner layer of porous bricks. The molten salt permeates the bricks and solidifies, providing a furnace lined with the same active salts as those used in this Aldip process.

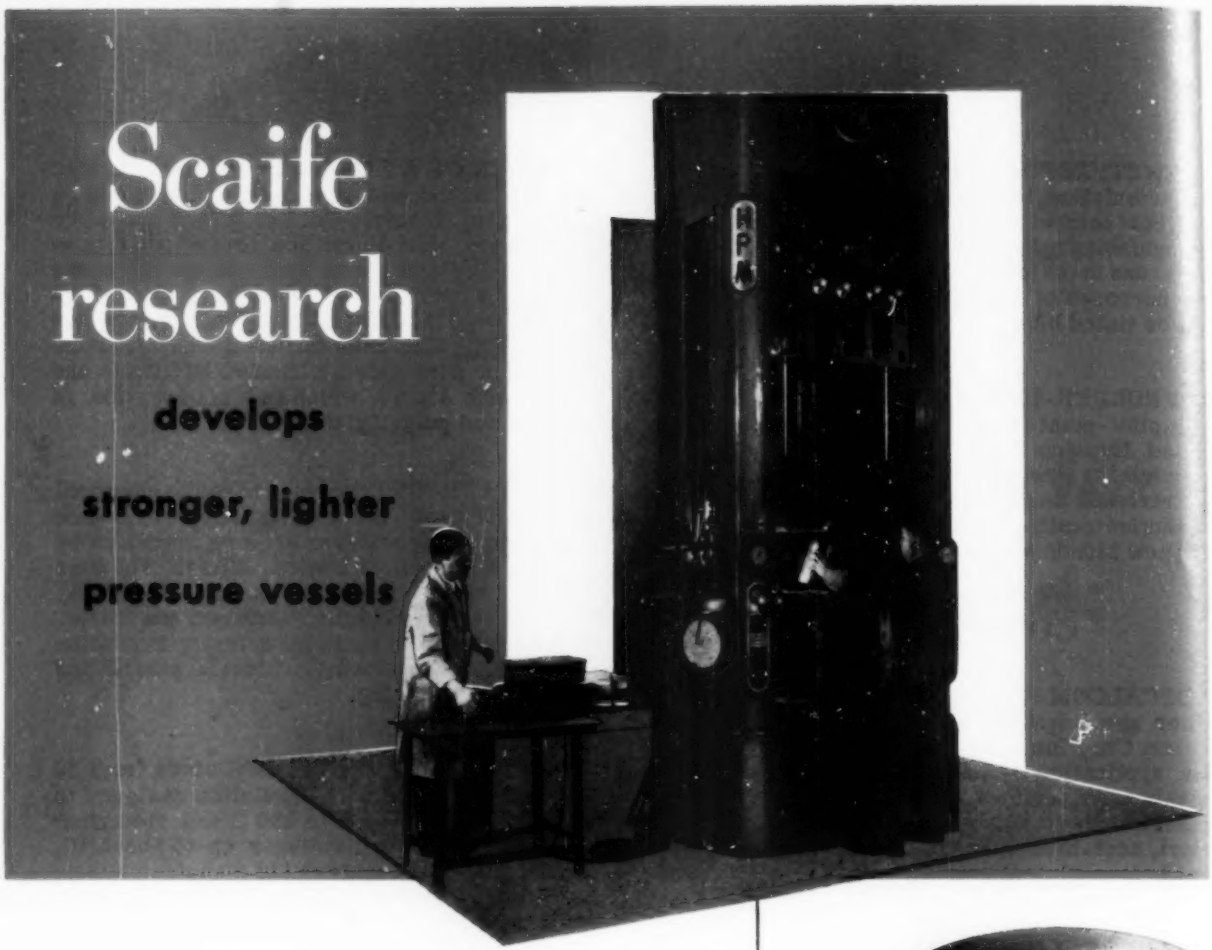
SURFACE DEFECTS found on continuously cast products can be eliminated or reduced by using a die that has shallow grooves in the working surfaces parallel to the die axis. British Patent 667,473 covers this technique that is said to impart excellent surface finish to an uminum alloy containing 12 percent silicon.

A PRACTICAL METHOD for electrodepositing aluminum at room temperature has been worked out at the Bureau of Standards. The bath consists of an ether solution of aluminum chloride and lithium hydride from which a dense, ductile deposit 0.050 in. thick has been prepared. Ap-

(continued on page 9)

Scaife research

develops stronger, lighter pressure vessels

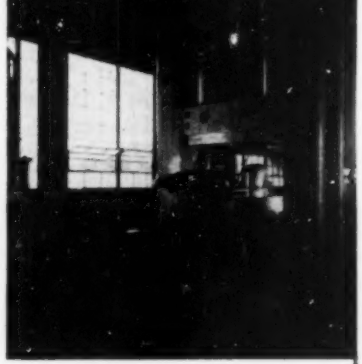


The pressure vessels and deep-drawn shapes being made today in the Scaife factory are *better* because of scientific research in Scaife Laboratories. For example, the development of the new Scaife Dura-Lite LP-Gas Cylinder included a complete study of the deep-drawing process, using half-size parts made on the research department press shown above. This procedure, supplemented by complete metallurgical, physical, chemical and specialized studies, permits accurate evaluation of various materials, drawing methods and processing procedure. The result is a better, more serviceable product designed and made on sound engineering principles.

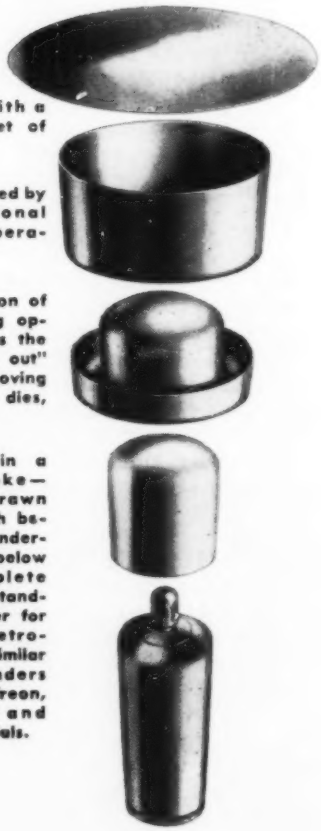
SCAIFE COMPANY

OAKMONT (Pittsburgh District), PENNA.

Makers of Pressure Vessels for Air, Gases and Liquids



Here is the "big brother" of the press shown at the top of the page. Full-size cylinder-half has been formed in one stroke of the press (see right) and is being removed for processing and assembly.



Starting with a circular sheet of steel—

a cup is formed by a conventional drawing operation.

A continuation of this pressing operation turns the cup "inside out" without removing it from the dies,

completing—in a single stroke—the deep-drawn shape, which becomes a cylinder-half. Shown below is the complete cylinder, a standard container for liquefied petroleum gas. Similar Scaife cylinders are used for freon, acetylene and other materials.

plication of the process to electroforming parts and for protective coatings is anticipated.

NO EXPENSIVE SLIDES or loose cores are needed in a new method of producing raised lettering on the sides of die cast parts. The lettering is placed on swivel blocks mounted on fulcrum pins so that ejection of the casting causes the swivel blocks to swing outward, thus releasing the casting without the need for extra rack and pinion action. This technique will work only on shallow impressions.

AN ELECTRO-EROSIVE METHOD has been developed in the Pittman-Dunn Labs at Frankford Arsenal for machining tungsten carbide and other hard metals. The process is claimed to be predominantly one of arc cutting in which a deposited dielectric film of sodium silicate directs the arc toward the cut where erosion take place.

CHROME-PLATED PARTS subject to fatigue loads have been designed conservatively because of strength reduction due to plating. United Chromium, Inc., New York 17, has come up with Unichrome SRHSCR-110 solution which eases this problem. For a part plated to 0.0001 in. the increase in cross-sectional area to compensate for plating can be reduced from 35 to eight percent.

TESTING

HOT RADIOGRAPHY is a process used by Sam Tour & Co., of New York City in the inspection of partially completed welds on hot sections of pipe and valves at temperatures as high as 1,200 F. X-ray photographs reveal welding defects.

PAPER TENSIOMETER, developed by GE, controls tension of paper as it goes between calender rolls during production mechanism is expected to hold the tension of moving sheet constant regardless of freeness, dryer temperature, moisture content, consistency or friction load variations.

"ELECTRICAL CHEMISTS" in the form of automatic spectrometers tell Ford engineers the precise composition of metals. Sample to be analyzed is exposed to a 25,000-v spark which immediately sets it ablaze. The ultraviolet light of each burning ingredient is sorted by the optical instrument and picked up by photo-electric tubes which record data on dials.

NO AUTHORIZATION is needed from the Atomic Energy Commission to obtain 40 milligrams of Carbon-14 from Nuclear Instrument & Chemical Corp., Chicago 10, Ill. Labeled d-glucose, the radioactive material emits about two million particles per minute, sufficient for many routine tests.

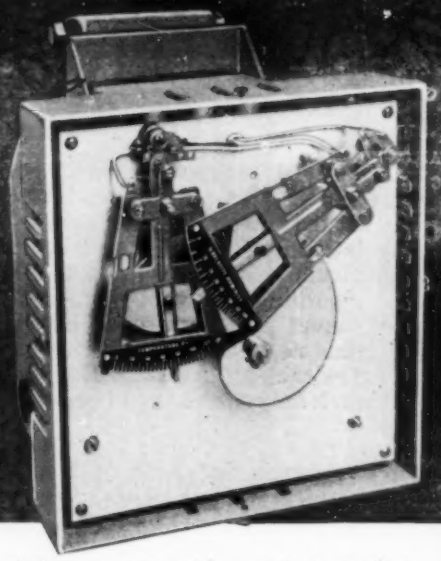
A "ROAD" SERVICE has been set up by Sperry Products, Inc., Danbury Conn., to provide engineers and equipment for investigating defects in metals and plastics by non-destructive test.

FIGURES FLY faster than ever through a new electronic digital computer, called MANIAC, at the Los Alamos Scientific Laboratory of the University of California. Machine does in an hour and a half a mathematical problem which took one of its predecessors, the ENIAC, 24 hr. It is much smaller in physical bulk than is the ENIAC and is able to do its job with only 3,000 electronic tubes. MANIAC means Mathematical Analyzer, Numerical Integrator And Computor.

THIS MONTH'S COVER

The electronic computing machine pictured on this month's cover is one that not only tackles weighty problems but also "worries" about the accuracy of its solutions. Developed by Raytheon Manufacturing Company, Waltham, Massachusetts, for the Office of Naval Research under contract with its Special Devices Center, the computer is called "Raydac," an abbreviation of "Raytheon Digital Automatic Computer." It will be shipped to the Naval Air Missile Test Center at Point Mugu, California where it will be used as an intelligence center to analyze performance information in connection with the naval guided missiles program.

DIE CASTING prevents "profit corrosion"



CASE HISTORIES FROM MT. VERNON FILES

Nothing is so detrimental to profitable production as *waste of time and material.*

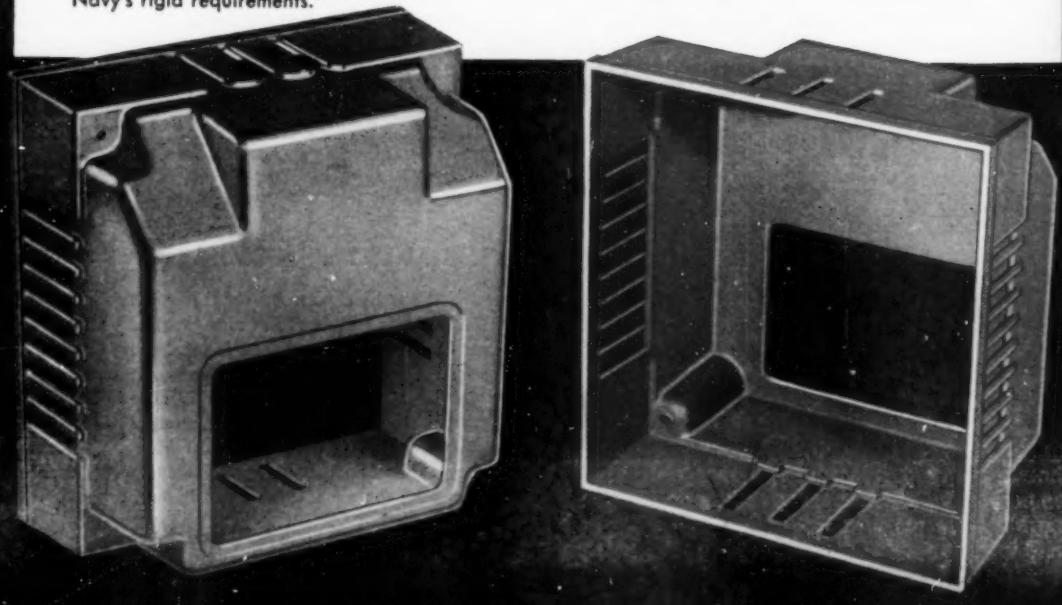
That's why you can benefit by giving serious thought to die casting, for die casting is industry's high-speed, cost-cutting method — promoting economy from start to finish on any production job.

Take for example, this temperature and humidity measuring instrument, used by the U. S. Navy to maintain non-corrosive atmospheric conditions aboard mothballed ships: Definite savings are realized by die casting the housing, because die casting produces this component *instantly*—and with maximum economy of metal. Not only are costs held down, but a superior product is obtained—strong, light, good looking, and adaptable to any type of finish.

Says The Instruments Corporation: "This Mount Vernon casting has proved itself to be the most satisfactory as well as the most economical housing that could be produced for the purpose. We consider it amply fulfills the Navy's rigid requirements."

Whenever *you* need a part or product made, therefore, don't forget die casting. Let us know your problems; send us your specifications. We've steered numerous manufacturers to high-output, low-cost production . . . shown them how to prevent *time waste* and *material waste* from eating into their profits.

MT. VERNON
DIE CASTING CORP.
MT. VERNON, NEW YORK



Perspectives — DESIGN AND DEVELOPMENT

PLASTICS IN EASY SUPPLY

The plastic supply situation has changed markedly since last year, when the demands of the remobilization program, insufficient manufacturing facilities, and the use of essential chemical intermediates in the production of compounds other than plastics combined to produce a severe shortage. Now there seems to have been built up enough inventory for military needs so that even the less abundant plastics have been taken off allocation; materials manufacturers have built and are building additional production facilities; and the chemical intermediates in question are in better supply either because of increased production or lessened demand from other quarters. It is now possible to get any plastic and for quick delivery, except polyethylene.

The end of the styrene monomer shortage caused by the shortage of benzene, has eased the supply of various polyester resins based on styrene and polystyrene. They are all freely available now.

Polystyrene manufacturers are heavily committed to construct additional plants. Monsanto, for example, has a new unit, Port Plastics, near Cincinnati, that is expected to be in production early next year, increasing the company's total capacity of styrene plastics by 40 percent. The capacity of its Long Beach, Calif., unit was doubled last year; and, when its current expansion is completed, the monomer plant in Texas is expected to satisfy the needs of both Monsanto and the government's synthetic rubber plants.

Polyester resins, used largely in the production of reinforced plastics, are plentiful; new facilities will make them more so. American Cyanamid has a new plant coming along in California which is expected to be in production later this year, and Plaskon is about to market a new line of polyesters that will be competitive in price with those of other companies.

THERMOSETTING PLASTICS

Phenol is no longer a bottleneck for the phenolic resins. Durez is planning to double its phenol capacity. Although this is not intended for the open chemical market, it will allow the company's production of phenolformaldehyde to expand. General Electric is scheduled to double its capacity for the production of the nitrile rubber-phenolic blends. Reichhold is increasing by 50 percent phenol production at its Alabama plant, at the same time increasing its resin production. At this company's main plant in Detroit, a further 25 percent increase in phenolic and urea resins, above the large increase made last year, is slated. Facilities are being added at the Elizabeth, N.J. plant for laminating and impregnating resins. A new plant is also in prospect in Montreal.

Although the applications of melamine and urea resins have continued within the same well-defined areas in which they have figured for some years, there was not enough of either to meet demand last year despite an increase in production. A further expansion is projected that will alleviate still more an already eased situation.

MOLDED NYLON

The percentage of molding powder in the 130,000,000 lbs. of nylon produced cannot yet be revealed, indirectly because of the government's wish to keep secret the amount being used for military purposes. However, this much can be said: that each six-months' period in the past

(Continued on page 115)

lower costs less breakage

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Costs were reduced $2.00 per thousand, and rejections practically eliminated on this saw-tooth washer, when INSUROK T-815 mat-base laminate replaced a linen-base laminate. Rejections were less because T-815 punched easier and reduced edge breakback.

Material costs were cut 26% and breakage greatly reduced during punching and riveting, when INSUROK T-610 paper-base laminate replaced a canvas-base laminate for this defroster panel. In addition, warpage was no longer a problem.

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few years has shown a marked increase over the preceding six-months period; and further, the figure is a great deal higher than most people imagine. Accordingly, Du Pont greatly increased production in the fall. Presumably the stockpile of assault wire and other nylon military applications has become ample enough to release the material from allocation, which means that the design engineer can freely include it in his plans without danger of disappointment when it comes to production.

FLUOROCARBONS AND SILICONES

Development of fluorocarbon plastics has proceeded rather slowly because of their high cost and restricted applications. Hence their virtual withdrawal from the civilian market when they were called on for military applications. Increased production of Teflon last winter, and a falling off of certain aircraft applications, has resulted in the material's being taken off allocation. There is enough of it available now for the foreseeable future. While Kellogg's Kel-F has never been under allocation, it has been mostly available for priority-rated orders. That situation has eased, and a new unit of the Jersey City plant, now under construction, is scheduled to increase production of the resin five-fold by the fall. Bakelite's fluorothene, of the same composition as Kel-F, is still in the pilot stage of production as it endergoes further development.

There is some variation in the availability of the many forms of silicone resins, though in general the design engineer can count on getting any of them in a reasonable time. Varnishes for electrical purposes are available within 30 days or so. Silicone rubber, which has been in heavy demand for specialized military applications, is rather tight, but it is to be had. Dow Corning's $15,000,000 plant expansion will make the silicone situation easier perhaps six months from now.

POLYETHYLENE

Production of upwards of 70,000,000 lbs. (it was 25,000,000 lbs. as recently as 1948) is still very far from satisfying the demand for polyethylene, and so new customers for familiar applications of the material and potential customers for new products are not likely to get too substantial quantities for some time to come. As of April, the allocation of polyethylene was 32 percent military, 28 percent essential civilian uses, and 40 percent for the free market. One recent development — polyethylene-coated paper -- is absorbing every pound in sight. It has been estimated that the present installed paper machinery could take up the entire production of polyethylene. Several companies have a capacity of some 7,000,000 lbs., yet all of them together can only get hold of some 10,000,000 lbs. at the present time. As more polyethylene becomes available, this packaging outlet will be a formidable competitor.

OTHER PLASTICS

There have been few striking developments of late in cellulosic plastics except for butryrate pipe. As a result, there was an oversupply of cellulosics until shortages developed in other plastics and end-users fell back on them as suitable for their applications even though they cost more than the types they replaced. Acetate eased off first, then butyrate and ethyl cellulose, which has been a preferred material in certain military applications because of its high impact strength and relatively low water absorption. But in April ethyl cellulose was removed from regulation under Order M-32 since it became available in ample supply.

Extensive production facilities have long existed for both acrylic sheet stock and molding compounds. The cutback in automobile production has hit molders of components in this field, so the material is easy to get.

The expected demand for vinyl film sheet and molded resins by the military has still not materialized, and in its absence, together with a falling off in the buying of certain consumer items, a comfortable margin of resin is on the market. That holds for polyvinyl chloride, the chloride-acetate copolymer and the vinylidene chloride copolymer (saran).

Notes on a Calendar Pad:

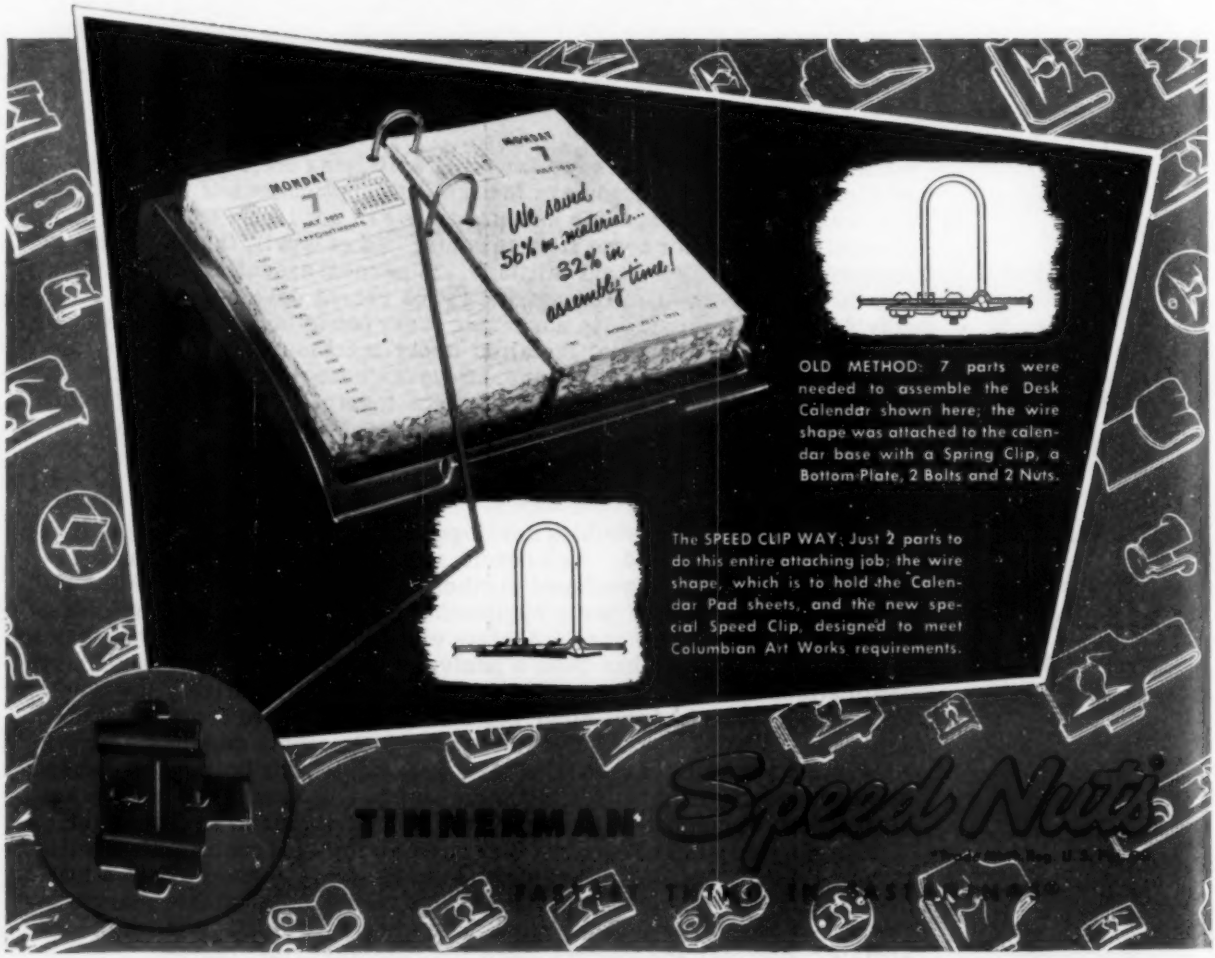
"We saved 56% on material... 32% in assembly time!

Desk Calendar Manufacturer makes "up-to-date" Savings by switching to Tinnerman Speed Clips

Here's how Columbian Art Works, of Milwaukee, Wisconsin, makers of quality desk calendars, recently checked their own production methods and picked up this amazing time and material savings! For many years they used 6 parts, plus a wire arch brace, to assemble and fasten one of their popular calendar pad models. Today . . . the Speed Clip way, this entire operation is done with 2 parts—the wire shape, and one multiple-function, special Speed Clip. The result is a saving of 32% in assembly time and 56% in material costs!

Savings like these are worth thinking about! Before too many sheets are torn from your calendar pad, make a date with your Tinnerman representative for expert advice on fastener engineering. There may be a "SAVINGS STORY" in your fastening assemblies. Meanwhile, write for a copy of the FREE booklet: "SAVINGS STORIES", TINNERMAN PRODUCTS, INC., Dept. 12, Box 6688, Cleveland 1, O. *In Canada:* Dominion Fasteners, Ltd., Hamilton, Ontario. *In Great Britain:* Simmonds Aerocessories Ltd., Treforest, Wales. *In France:* Aerocessoires Simmonds, S.A., 7 rue Henri Barbusse, Levallois (Seine), France.

Whatever you make—from Calendar Pads to Clothes Dryers—think first of TINNERMAN for better Fastening Engineering.


MONDAY
7
We saved 56% on material... 32% in assembly time!
OLD METHOD: 7 parts were needed to assemble the Desk Calendar shown here; the wire shape was attached to the calendar base with a Spring Clip, a Bottom Plate, 2 Bolts and 2 Nuts.
The SPEED CLIP WAY: Just 2 parts to do this entire attaching job; the wire shape, which is to hold the Calendar Pad sheets, and the new special Speed Clip, designed to meet Columbian Art Works requirements.
TINNERMAN
Speed Nuts

Handouts Cost Plenty

THERE IS AN EXPRESSION, "Ignorance of the law is no excuse." To the contrary, it would be humanly impossible for even a hundred people to possess in sum total a complete knowledge of all the laws on the statute books, to which must be added the thousands of "directives" that have the force of law, issued by the innumerable government agencies. Obviously there is little or no sense to the expression, "Ignorance of the law is no excuse", when applying it to the often inane or stupid laws enacted by mere man.

However when it comes to the laws of nature it can always be truly said, "Ignorance of the law does not change it." That is a fact only too well known to scientists and engineers.

There is always a great temptation for humans to resort to a play on words when trying to do something that is counter to the laws of nature. This is the favorite trick of politicians when they offer everybody something for nothing, if they are elected. Obviously it cannot be done, but by juggling words, ignoring laws of nature and resorting to a few half-truths or less, a glib talker can often convince his audience.

In a very fine speech, "Equality and Security", Dean Russell of the Foundation for Economic Education, Inc., points out some of the consequences when a free people allow themselves to be misled into breaking or ignoring the basic laws of nature. It is impossible to even merely mention here the many points made by Dean Russell in his discussion. However, every engineer reading it will be impressed and some will awaken to the great danger this nation is facing.

It is an unexplainable fact that to most people the word "government" means some mysterious power that must be feared, respected and obeyed. It is considered improper and unethical to name individuals in government unless it is to praise them. It is never the president who is to be blamed. The "administration" erred or "sources" close to the White House are responsible. Congress did this and such-and-such a committee did that. It was the attorney general's office that "failed to prosecute", not the attorney general by name.

Presumably it is not always feasible to name names and there is a sort of a code that frowns upon it. Be that as it may, the fact contributes greatly to the irresponsibility of many of the government operations.

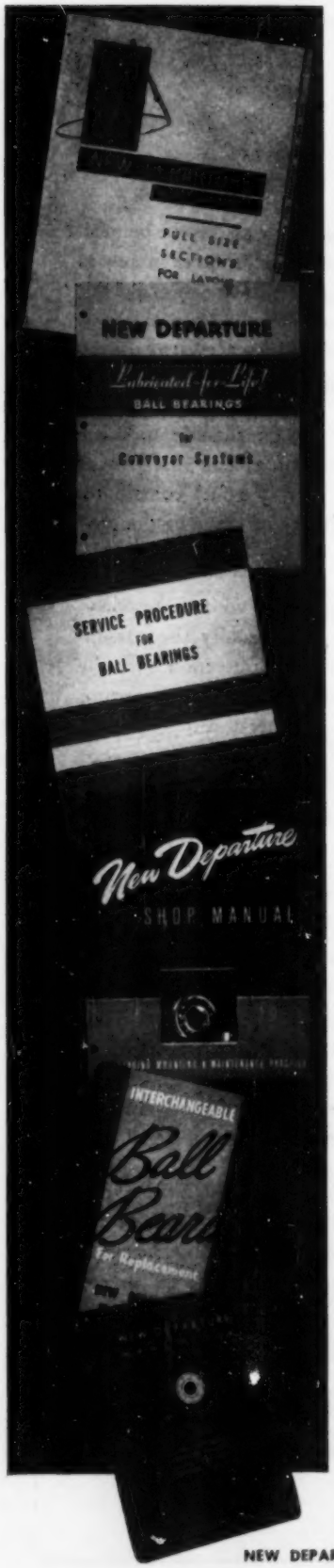
Whenever there is authority without responsibility there is inefficiency and usually also corruption. That is why government operation over the long run is terribly inefficient and so often corrupt. The fact is axiomatic. And because it cannot be proved few people really believe it. Hence they willingly reach out for the government "handouts", and blind themselves to the price they must eventually pay.

In his brochure Dean Russell makes an excellent point when he states—"People honestly seem to believe that the phrase 'government as servant' means that government should give them material benefits directly or through special laws. They don't seem to realize that when the servant gains the power to support the master—and when the master becomes dependent on the servant—the former relationship becomes completely reversed."

The greatest contribution that engineers can make to their country and themselves is that of doing everything possible to reestablish the formerly existing relationship between those elected or appointed to political office and the people. Let the latter again be the master.

G. F. Zodenholt

Complete Information on Ball Bearings



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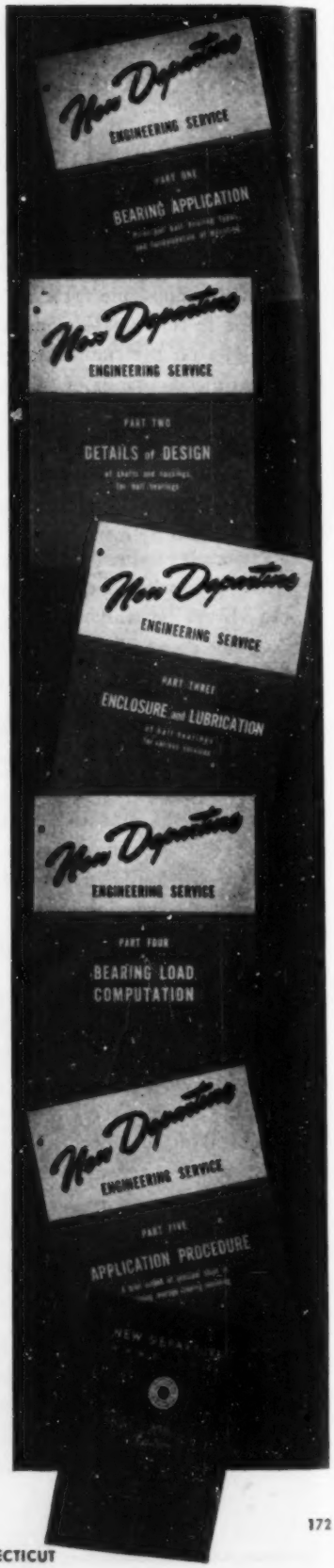

NEW DEPARTURE
BALL BEARINGS

Nothing Rolls Like a Ball

172

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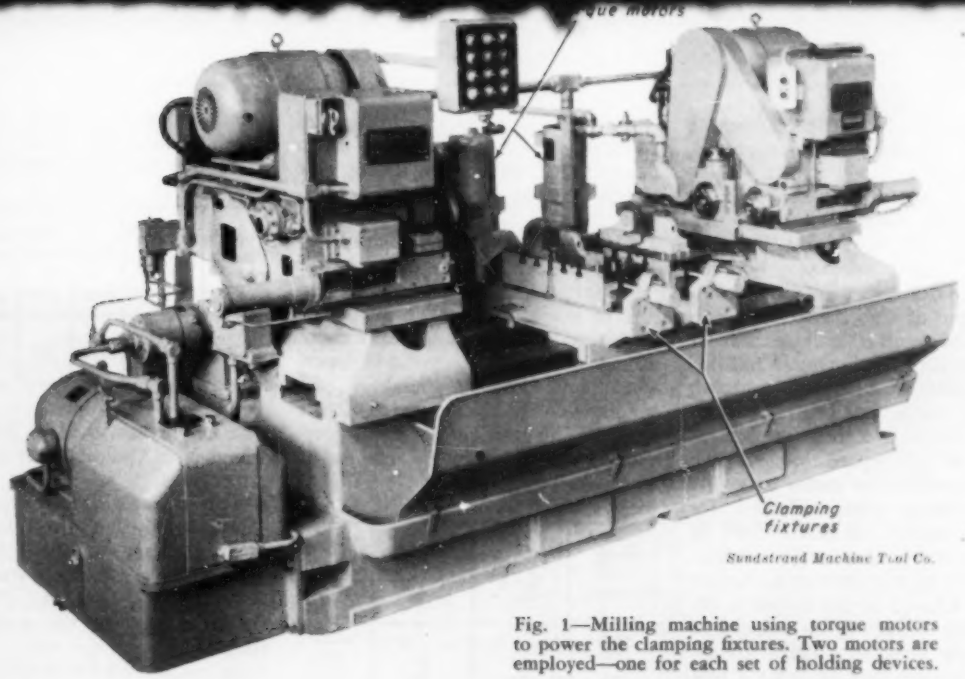


Fig. 1—Milling machine using torque motors to power the clamping fixtures. Two motors are employed—one for each set of holding devices.

The Torque Motor As a Control Device

New interest is being shown in the torque motor as an actuator in control systems. Its advantages are: unlimited travel, either fast or cushioned operation and a practically linear speed-torque characteristic.

ROBERT KAPLAN
ALBERT J. BROTZ
Howell Electric Motors Company

THE CHIEF DISTINGUISHING FEATURE of the torque motor is the ability to withstand locked rotor currents for long periods of time. These periods may represent from 5 to 100 percent of the duty cycle of the motor. In other respects, the torque motor is similar to conventional types. It can be made for operation at all commercial voltages and frequencies and for use on direct current, single phase or polyphase circuits. This similarity applies also to the range of ratings available and to mechanical features such as enclosures, bearings and built-in gearing.

The design of a polyphase a-c torque motor is typical of this class of machines. It is known that when rated line voltage is applied to the terminals of a conventional squirrel cage motor, the initial inrush current is 5 to 6 times greater than rated current. If the rotor is locked and the heavy current allowed to persist for some length of time, the motor burns out.

In a squirrel cage motor, there are two motor parameters that can be changed to alter locked rotor current. The parameters are resistance and reactance. To decrease the inrush current, either or both resistance and reactance must be increased.

An increase in rotor reactance results in a decrease not only in inrush current but in locked rotor torque as well. In contrast to this, increasing rotor resistance up to an optimum point causes an increase in developed torque while limiting locked rotor current.

The objective in designing a torque motor is to provide for the limitation of locked rotor currents. And, because of its beneficial effect on torque, added resistance is the limiting means chosen. The customary method of increasing the rotor circuit resistance in a polyphase squirrel cage torque motor is to use rotor bar and end ring materials having electrical resistivities from 6 to 10 times greater than that of copper.

In Fig. 2 is given a family of speed torque curves that are representative of squirrel cage motors. Curve *A* is based on a rotor having a conventional magnitude of resistance. Each of the remaining curves show the effects of adding progressively greater resistance in the rotor circuit. It is

noted, first, that each time resistance is added, a given value of torque is developed at a lower speed. Also apparent is the fact that locked rotor torque increases with added resistance up to and including Curve *D*. For Curve *E*, locked rotor torque drops back to a value lower than the maximum torque of Curve *D*. Thus, the optimum value of rotor resistance lies somewhere between Curves *D* and *E*.

Two points of interest concerning the torque motor can be noted from Fig. 2. These are the approach to linearity of the speed-torque curve and the fact that the motor exerts its maximum torque when stalled.

Torque motors are called upon to operate in one of three ways. Applying an arbitrary classification to torque motors, a Class I torque motor is defined as one which may be required to exert torque while in a stalled condition for periods ranging from a few seconds to many hours.

A Class II torque motor is one that is required to run for relatively long periods compared to the time stalled. Class III covers motors that are called upon to run at one speed or several speeds, usually considerably below the synchronous speed. In Class III applications, the motor is seldom—if ever—stalled. But by choosing a torque motor, the designer takes advantage of the linear torque-speed characteristic and of the fact that the motor can operate at high slip without destructive overheating.

It should be pointed out that the assigned classifications are arbitrary and are chosen to emphasize types of applications. Actually, there is no basic design differences among the motors used in the various classifications.

The rating of a torque motor is generally expressed in terms of the locked rotor torque developed and the percent of operating time during which the motor can remain stalled without damage. The torque is given in ounce-feet, pound-inches or pound-feet, depending on the magnitude of the values. The relationship of the percent duty cycle rating to minutes of actual operating time is:

Duty Cycle (Percent)	Max. Stalled Time (Min)*	Cyclic Rating (Sec.)	
		Stalled	Deenergized
100	Continuous	Continuous	—
50	60	30	30
25	20	15	45
10	10	6	54
5	5	3	57

* Motor should be allowed to cool to room temperature between operations.

It can be seen from this table that the percent duty cycle rating relates to cyclic operation. Thus, a torque motor with a 50 percent duty can be stalled for as long as 30 min in each hour of operation. In non-cyclic usage, the same motor can be locked safely for 60 min, providing it is allowed to cool to room temperature between operations.

For a given torque and percent duty cycle, the physical size of a polyphase torque motor decreases as the number of poles increases. This is illustrated as follows for one typical rating.

Torque Pound-Feet	% Duty Cycle	NEMA Frame Size			
		4 pole	6 pole	12 pole	16 pole
2	100	326	284	225	224

The number assigned by NEMA to a frame is an indication of its physical dimensions.

This is explained by the fact that shaft torque is a direct function of rotor diameter and field flux. The magnetic field rotating in space actually pulls the rotor after it. The greater the field strength, the greater is the force acting on the rotor. It is this force multiplied by rotor radius that produces shaft torque. By adding to the existing number of field poles, the motor designer increases the strength of the rotating field. Thus, a smaller rotor radius is needed to effect a given value of torque.

The number of stator slots required to accomodate the field windings of the motor is directly proportional to the number of poles. Therefore, it can be seen that an indefinite extension of above table is impossible, since the reduction in frame size soon limits the quantity of winding slots that can be accomodated.

A second limitation on the number of poles that can be used is the speed

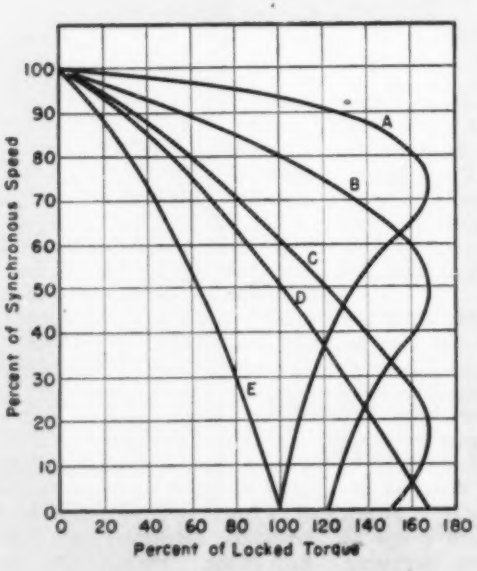


Fig. 2—Torque-speed characteristics of squirrel cage induction motors. Rotor resistance was increased progressively to obtain the different curves. Note that curves D and E—representing high rotor resistance—are almost linear. The performance characteristics of an ideal torque motor lie somewhere in the area between these curves.

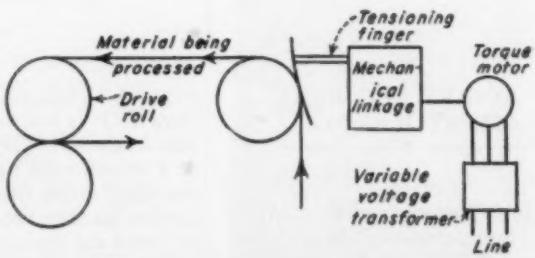


Fig. 3—Schematic of application of torque motor to provide adjustable tension on material moving through rolls. Tensioning finger acts as a friction brake on the material.

of the motor. The speed of an induction motor is given as:

$$S = 120 f/p$$

where S = speed in rpm
f = frequency of the line voltage
p = number of poles

For a constant frequency, such as that of the conventional 60 cycle supply, an increase in the number of poles causes a decrease in the speed. Thus, where the torque motor is to operate at a certain speed, the motor designer has no choice but to supply the correct number of poles to attain that speed.

Listed in Table I are the frame sizes used by one manufacturer for polyphase torque motors with from four to 16 poles.

Class I Applications

Given in Fig. 3 is a schematic of an application involving adjustable tension. Torque exerted by the motor causes tensioning fingers to work against the material being processed. The system may include a spring mechanism which relieves the tension when the motor is deenergized. When the particular material being processed calls for full motor torque, the motor is energized directly across the line. When the material size or strength is changed so that less tension is necessary, lower primary voltage is applied to the motor by means of the variable voltage transformer. It is important to note that the torque motor does not drive any of the processing system.

Some of the advantages of the torque motor over more conventional methods of applying force are apparent in the use of a torque motor release for a brake. Here, the motor might take the place of an electric solenoid. Fig 4 illustrates the use of such a motor applied to an elevator brake. The torque motor provides quieter operation and more positive action because of freedom from sticking.

The action of the torque motor shown in Fig. 4 is as follows: the torque motor and the winding machine motor are wired in parallel. When the motors are energized, the torque motor releases the brake against the tension of the spring which tends to hold the brake closed. When the power is cut off, both motors are deenergized and the spring sets the brake.

A further use of a Class 1 motor is for the operation of the retiring cam found in automatic elevators. The action of the cam is to release the door locking mechanism when the desired floor level is reached. The entire assembly is shown in Fig. 5. The torque motor is mounted above the cam, which is shown in the retracted position. When the elevator stops, the motor is energized and makes about one-half revolution before it is stopped positively by a metal link. The cam is thus extended forward in a position to actuate the door release. When the elevator is started again, the torque motor is deenergized and the cam is retracted by action of a spring.

The torque motor is frequently used as the power element in remotely operated control panels for d-c motors. The panel pictured in Fig. 6 is for the control of an elevator passenger motor. The contractors, which are mounted in four horizontal banks, are closed by means of cams. Torque motors drive the camshafts for starting accelerating, stopping and revers-

Table I—NEMA Frame Sizes for Torque Motors

TORQUE	PERCENT OF TIME LOCKED				
Pound-Feet	5%	10%	25%	50%	100%
4 Pole — RPM = Cycles × 30					
.5	A56	B56	B56	A66	A204
.75	A56	B56	C56	B66	A224
1.0	B56	C56	B66	A204	A254
2.0	B66	A204	A224	A225	A326
6 Pole — RPM = Cycles × 20					
.5	A56	A56	A56	A56	B66
.75	A56	A56	A56	A66	A204
1.0	A56	A56	C56	B66	A224
2.0	C56	A66	A204	A224	A284
3.0	B66	A204	A224	A254	A326
4.0	A204	A224	A225	A284	364
8 Pole — RPM = Cycles × 15					
.5	A56	A56	A56	A56	B66
.75	A56	A56	A56	A66	A203
1.0	A56	A56	A66	A66	A204
2.0	C56	C56	A203	A204	A254
3.0	A66	B66	A204	A254	A324
4.0	B66	A204	A224	A284	A326
5.0	A203	A225	A254	A324	364
10 Pole — RPM = Cycles × 12					
5	A56	A56	A56	A56	A66
.75	A56	A56	A56	C56	B66
1.0	A56	A56	B56	A66	A203
2.0	B56	C56	A66	A203	A254
3.0	C56	A66	B66	A225	A284
4.0	A66	A203	A204	A254	A324
5.0	B66	A224	A225	A284	A326
7.0	A203	A225	A254	A324	364
12 Pole — RPM = Cycles × 10					
.5	A56	A56	A56	A56	C56
.75	A56	A56	A56	B56	A66
1.0	A56	A56	A56	C56	B66
2.0	A56	B56	C56	B66	A225
3.0	B56	C56	A66	A224	A254
4.0	C56	A66	A204	A225	A284
5.0	A66	B66	A224	A254	A324
7.0	B66	A204	A225	A284	A326
8.0	A204	A224	A254	A324	365
10.0	A224	A225	A284	A326	404
16 Pole — RPM = Cycles × 7.5					
.5					
.75					A203
1.0					A204
2.0				A203	A224
3.0				A204	A225
4.0	A203	A203	A203	A224	A254
5.0	A203	A204	A204	A225	A284
7.0	A204	A224	A224	A254	A324
8.0	A204	A224	A225	A284	A326
10.0	A224	A225	A254	A324	354

Fig. 4—Torque motor used as brake release element on an elevator cable drum. When energized, the torque motor drives the sector gear until it stalls. The motor remains in the stalled condition as long as the drum is turning.

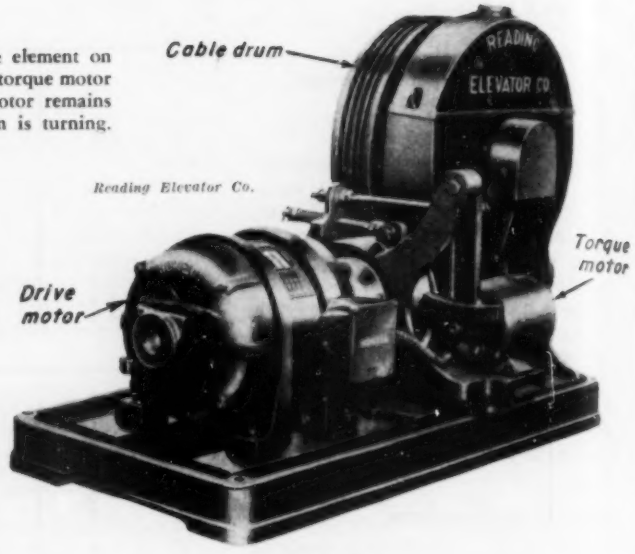


Fig. 5—Retiring cam used to operate a door latching mechanism is powered by a torque motor. Assembly below is mounted vertically, with the motor directly above the cam.

ing the main motor. For speed control, the contacts on the panel cut resistance in and out of the armature and field currents of the traction motor. By proper selection of camshaft speed and the shape of the cams, smooth acceleration and dynamic braking characteristics can be obtained.

The Sundstrand milling machine, Fig. 1, incorporates two small vertical torque motors (visible in the background) to operate the clamps that hold the material to be milled and centered. Since the material may be of various shapes and sizes, the clamps vary in design. The clamps move horizontally through a gear train. The two motors are controlled through one reversing magnetic starter, which is in turn controlled by two momentary contact push buttons marked "clamp" and "unclamp." The motors are energized only while the operator is pushing the button. In the operation of the machine, the operator pushes the "clamp" button and holds it until the motor stalls. He then releases the "clamp" button and pushes the "cycle" button which starts the milling and centering operation. When the work is done the operator pushes the "unclamp" button which backs off the clamps and releases the work. The torque motor provides secure holding in this application.

Class II Applications

Large valves are often actuated by high speed (two or four pole) torque motors. A large proportion of the motors so used are built to explosion resisting standards. The advantages claimed for motor operated valves are remote control, higher speed, greater ability to break away after long idle periods and decreased valve seating shock.

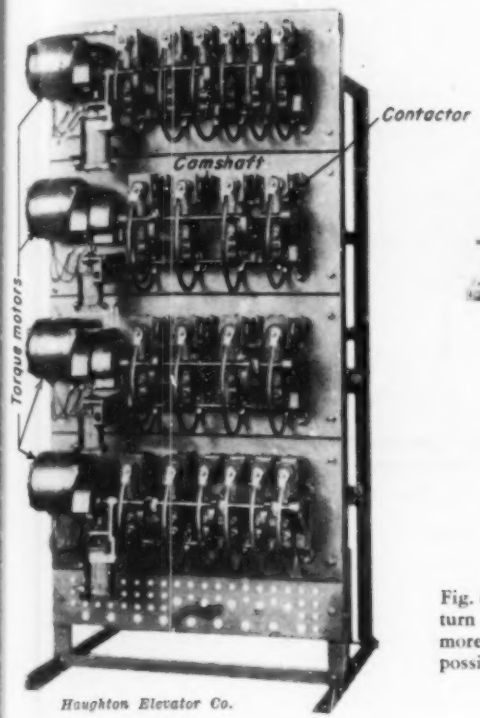
An interesting torque motor application is illustrated in Fig. 7. The device shown is an electromechanical remote control for drag scraper driving drums. This torque motor is of the reversing type. The purpose of the mechanism is to permit the operator to be located in a remote position such that he can see the scraper bucket in any location in the storage area. The operator controls the torque motor by means of a "Right", "Left", and "Neutral" spring actuated switch. While the master switch is on "Right" or "Left", it controls the direction of rotation of the torque motor. When the switch is returned to the neutral position the brake is automatically applied and the motor stopped.

The torque motor is connected by means of a worm gear reducer and roller chains to the clutch plates on each cable drum. The clutches are leadscrew-actuated and are arranged so that when the torque motor rotates clockwise, the clutch of one drum is engaged. This connects the drum to the main drive motor. This drum takes up the drag bucket cable, while the second drum idles, paying out cable.

Then, when the torque motor is reversed, the first clutch drops out and the second clutch is engaged. The idling drum becomes the driven unit, and the cable is pulled in the opposite direction.

Use of the single clutch motor prevents both clutches being applied at the same time. The torque motor is stalled under power when either clutch is engaged.

Positioning tables, requiring as many as 60 index positions per minute, are often driven by Class II torque motors. In most cases the table is driven through various types of gears usually of such magnitude that the inertia of the table is negligible. The problem involved here is to move the table from position to position in a fraction of a second so that time remains to handle the material brought into position. Variations of this type of table are used in loading containers automatically, and in automatic welding devices. The advantage of a torque motor in such applications is its rapid acceleration.



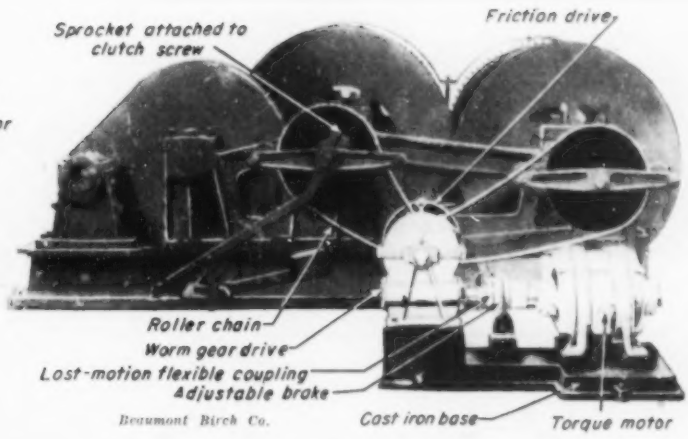


Fig. 7—Torque motor controls the engagement of two clutches in this cable drive. When torque motor rotates clockwise, the clutch of one cable drum is engaged, coupling it to the main motor. This action is reversed by reversing the torque motor.

Fig. 6—Bank of contactors for control of d-c motor. Torque motors turn the camshafts that actuate the contactors. This assembly is more flexible and provides smoother speed adjustment than that possible with conventional magnetic contactors.

Class III Applications

Application of this class of torque motor is found in reeling devices used in the winding and spooling of material, such as various types of paper or threads. The problem involved is to reel the material at approximately constant tension and constant linear speed. The need for constant tension is brought about either by the strength of the material being reeled or, even more likely, by the need for uniform tension in the layers of the reeled material. The desirability of constant linear speed is generally a result of the process involved. Usually, the material goes through some stage at constant speed before being taken up on the reel.

To illustrate the design problems involved in applications of this type, a typical case can be considered.

Assume a thread is to be reeled on a spool which is two inches in diameter when empty. The spool when full will have a diameter of four inches. The thread is of such a material and size that not over five pounds tension can be tolerated. Before the material is reeled, it passes through a solution which is of such makeup that the thread would be injured if allowed to remain in it too long and would not be properly treated if allowed to pass through the solution too rapidly. Assume the rate of passage of the thread must be maintained at approximately 300 ft per minute.

The motor speed needed to obtain a linear speed of 300 fpm on a two inch diameter spool can be determined by the elementary relationship:

$$\text{Speed} = \frac{300 \times 12}{2\pi} = 573 \text{ rpm}$$

The torque required is equal to the tension multiplied by the radius of the spool or five pound-inches. One point on the motor speed-torque curve now has been determined; i.e., five pound-inches at 573 rpm. The second point is determined from the requirements when the spool is full or:

$$\text{Speed} = \frac{300 \times 12}{4\pi} = 287 \text{ rpm, and}$$

$$\text{torque} = 5 \times 2 = 10 \text{ lb-in.}$$

It is obvious that if the drive motor has a perfectly linear speed torque curve, a motor designed to meet the first point would also meet the second point. The torque motor has characteristics that closely approximate this requirement. However, normally the speed-torque curve as shown in Fig. 2 deviates from the straight line and some compromise must be made.

The manner in which this compromise is made is shown in Fig. 8. The straight line indicates the ideal motor characteristics required. Curves *A* and *B* show the actual performance that can be obtained with torque motors. Usually in reeling a material, the inner fibers can be wound slightly tighter than the outer fibers and a curve as shown at *A* is used. When the opposite condition exists, a motor designed in accordance with curve *B* is used. Tension can be varied by use of an adjustable voltage transformer.

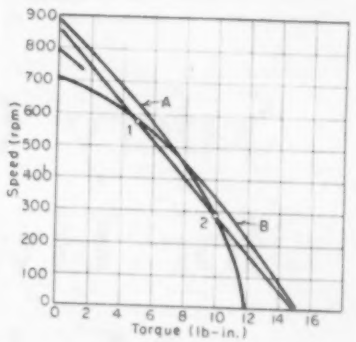


Fig. 8—Straight line represents speed-torque characteristics required to control material tension in a winding or spooling machine. Curves A and B show performance actually obtainable from torque motors

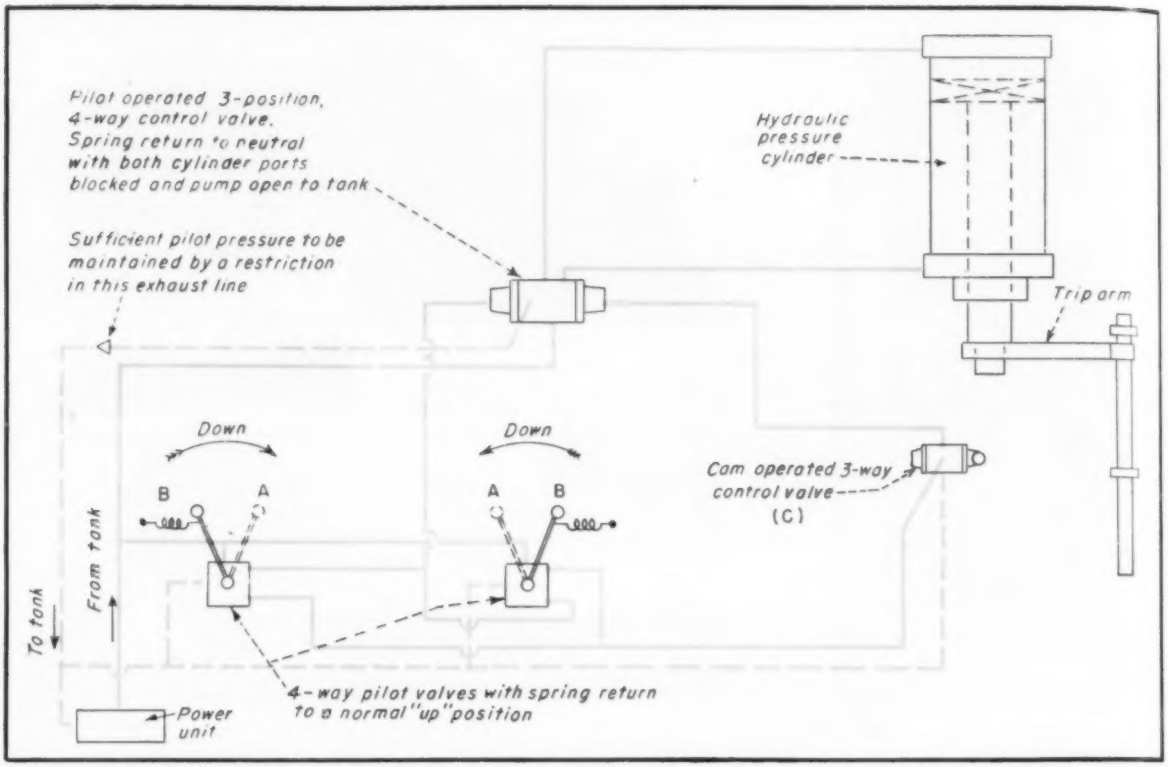

Pilot operated 3-position, 4-way control valve. Spring return to neutral with both cylinder ports blocked and pump open to tank
Sufficient pilot pressure to be maintained by a restriction in this exhaust line
Hydraulic pressure cylinder
Trip arm
Down
Down
B
A
A
B
Cam operated 3-way control valve (C)
From tank
To tank
4-way pilot valves with spring return to a normal "up" position
Power unit

Fig. 1—Two-hand safety control for hydraulic press. This circuit makes it impractical for operator to tie down either handle in an attempt to nullify safety feature. Should the controls be tied down, the machine goes through only one half of a cycle. Both handles must be released before the pistons retract to their rest positions.

Safety Circuits for Hydraulic Machines

H. L. STEWART
Logansport Machine Company, Inc.

FOR VARIOUS REASONS, safety has become a prime consideration in the design of industrial machines. In hydraulic equipment—as in other types—the specified safeguards must be provided by the designer of the control circuit.

Hydraulic press circuits, as well as other hydraulic machine circuits, can be designed to give the operator ample protection. On large hydraulic presses that are operated by two men, circuits can be designed so that all hands must be on the controls before the press ram starts to descend. If either man releases either hand, the press ram stops or returns to the starting position. If the controls are tied down, the press goes through only one cycle, then stops. The engineering of a hydraulic circuit often becomes a battle of wits between designer and operator. The latter often displays ingenuity in circumventing safeguards.

Safety to the machine is another consideration. In many of today's complicated machines, it is necessary that safety interlocks be installed wherever possible. If for any reason the hydraulic or the mechanical motion should fail, safety controls immediately stop all movement or release pressure from the movement so as to eliminate strain on the equipment. The jamming of a work piece during the machine cycle may cause extensive damage if controls are not properly designed.

The circuits described are representative of safety circuits that have been used with success.

TWO-HAND CONTROL. The circuit sketch, Fig 1, shows a two-hand safety control for a hydraulic press. By the use of two four-way, manually operated pilot valves to control the master valve, safe operation of the press is assured at all times. The cam operated three way valve controls the length of stroke and also shifts the master valve back into neutral position when the ram reaches top of desired stroke. This prevents overheating of the oil during long standby periods and relieves undue operating pressure and excessive pull on motor during these periods.

When the handles of both pilot valves are shifted to position *A*, the press ram moves downward. Both handles must be held in this position until the ram completes its stroke. If the operator removes either hand, the ram stops.

When both handles are free, they return to position *B*. The press ram retracts until the cam operated

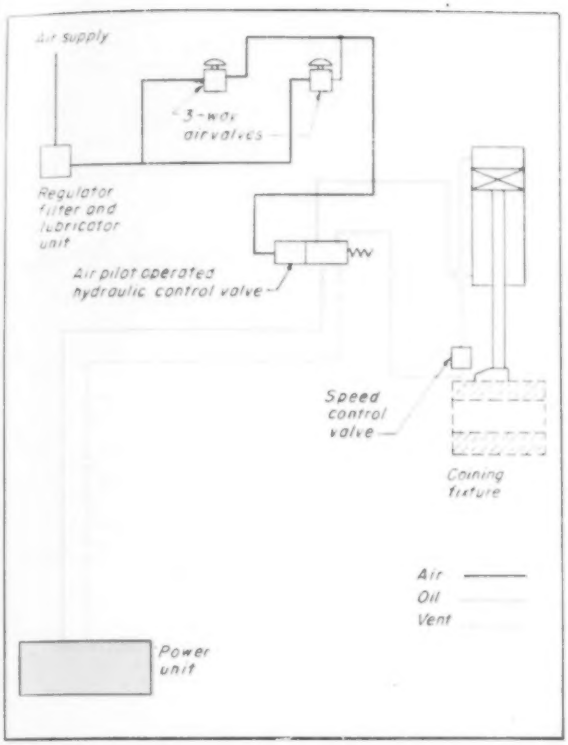


Fig. 2—Safety circuit using two manually operated air valves. Incorporation of air in machine operation speeds the action of safety devices. This is a two-hand type of control.

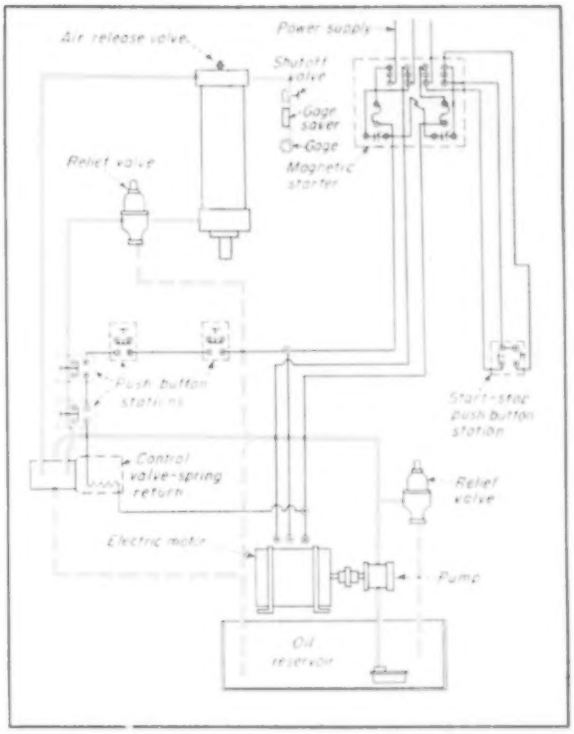


Fig. 3—Four-hand control circuit for a machine requiring two operators. Both hands of both men must be safely occupied for ram movement to begin and continue.

valve *C* is shifted by the adjustable collar connected to the trip arm. The ram stops at this point. Both handles must be shifted together and released together to obtain the desired press action. The operator is not inclined to tie down either handle, since he would have to release it again for return of the ram.

Action of a safety circuit can be speeded up by the use of air. Such a circuit, pictured in Fig. 2, incorporates two manually operated air controls. These small three-way air valves assure fast operation of the pilot operated master control valve. If the operator should remove either hand from the valve handles, the piston of the power cylinder retracts to its original position.

At the start, the operator places the workpiece into the coining fixture. Then, he shifts the handles of both three-way, two-position, spring-return air valves. Both hands are occupied. Air flowing to the pilot connection on the four-way, spring-return hydraulic control valve shifts the piston of this valve. Thus, oil is admitted to the blind end of the coining cylinder through the ball check of the cam-operated speed control valve.

After the piston has advanced and performed the coining action on the workpiece, the air valves are allowed to return to their original positions. With the release of pilot pressure, the piston of the hydraulic control valve shifts, directing oil to the rod end of the coining cylinder. The piston retracts rapidly until the cam contacts the roller of the speed control valve. The oil flow is then metered through an orifice, slowing the movement of the piston for the remainder of the stroke.

The use of an air pilot circuit does not alter the basic principles of designing for safety. The devices incorporated in an all-hydraulic control can be duplicated in all-pneumatic or air-hydraulic circuits also.

FOUR-HAND CONTROL. Certain large machines require the attention of two or more operators. Both of these men, who may be standing some distance apart from one another, must be protected. To avoid long runs of hydraulic piping, it is often convenient to use electrical interlocks.

In the circuit shown in Fig. 3 both operators must have their hands on the electric pushbuttons to energize the solenoid of the master valve. The shifting of the master valve controls downward movement of the hydraulic ram. The release of any one pushbutton by either operator causes the ram to retract.

The electrical circuit used is simple, all pushbuttons being connected in series. The remoteness of one control station from another is a minor consideration since the electrical wiring between stations can be of any length. Long lengths of hydraulic tubing on the other hand are higher in first cost, increase the possibility of leaks and cause appreciable hydraulic losses.

MACHINE SAFETY. Often the designer must provide safeguards for the machine as well as the operator. This is especially true when the machine is complex and expensive. If the human element were not considered in the design, the machine would be liable constantly to damage by careless use.

Some of the safety features that can be provided for such machines are illustrated by Fig. 4. By shifting the valve handle to the emergency stop position, the machine cycle can be stopped immediately. Second, because of the interlocking valves Nos. 25 and 26, the turntable cannot rotate until the pistons of the spinning and staking cylinders are

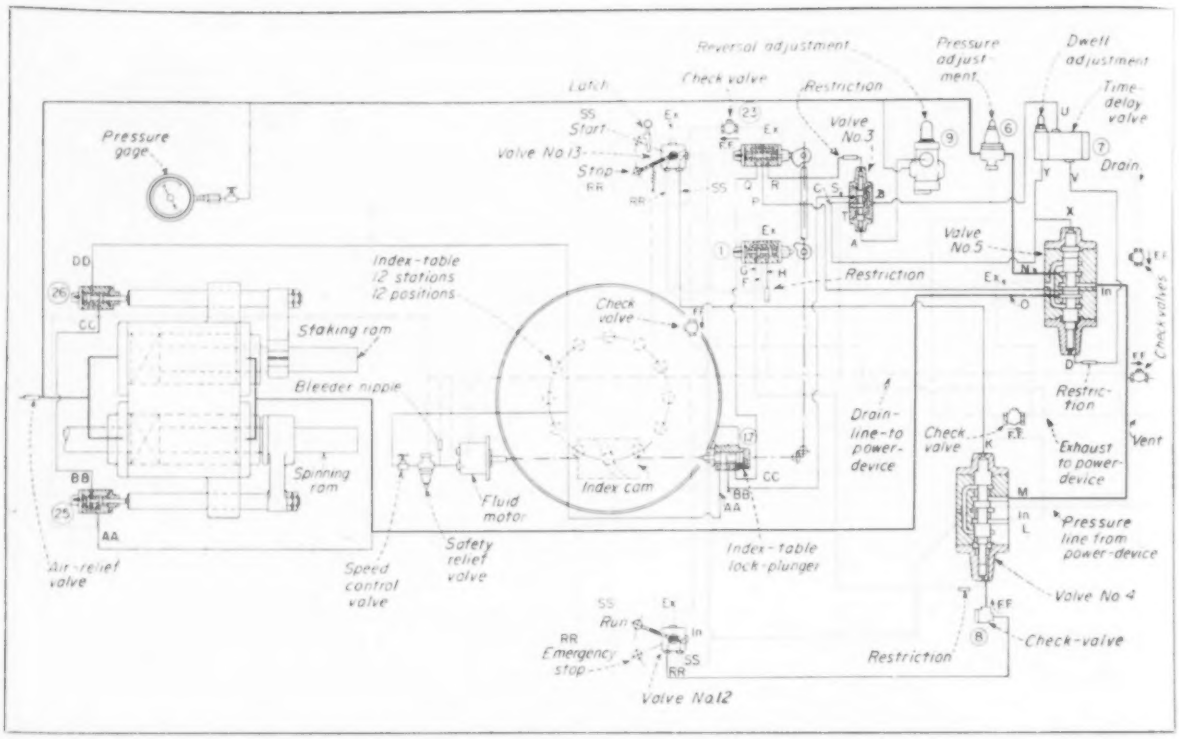


Fig. 4—Machine safety is an objective behind the design of this circuit. The turntable cannot rotate unless the rams are clear of the table. This prevents damage from untimely table movement as could occur should the extended rams become jammed.

in the up position. No oil can be admitted to the turntable drive motor unless the plungers of these interlocking valves are depressed.

If the turntable meets resistance such as would be caused by jamming of a workpiece, the table stalls without damaging the machine. This feature is controlled by the setting of the hydraulic relief valve that is set just high enough for the table to move under normal loads.

In operation, the handle of valve No. 12 is normally in the run position. It remains in this position except when it is required to stop the cycle for an emergency. For continuous repetitive action, the handle of valve No. 13 is latched in the start position. For a single operation, the handle is momentarily shifted to the start position, then released. The press goes through one cycle and stops automatically.

With valve No. 12 in the run position and valve No. 13 in the stop position, all valve pistons are as shown in Fig. 4. The pump supply is directed to the inlet port of valve No. 4, then is vented directly back to the reservoir. The size of the return line is reduced to provide sufficient back pressure to operate the pilot valves. Pump supply is also directed through valves Nos. 12, 13 and 1 back to port J of valve No. 4. The piston of this valve is thus held in the position shown.

When the handle of valve No. 12 is momentarily shifted to the start position, oil pressure travels from port *SS* to pilot chamber K of valve No. 4. Movement of the piston of this valve admits oil to the inlet port of valve No. 5. Then, oil reaches the top of the power cylinders at a pressure governed by the setting of the relief valve No. 6. Pressure is also directed to the inlet port *P* of valve No. 2, then out port *Q* to port *CC* of valve No. 17, holding the index table lock plunger in place.

From port *BB* of valve No. 17, oil flows to valve No. 5 and to the time delay valve No. 7. Now, the rams of both work cylinders advance. At the end of the down strokes, pressure build up in the line opens valve No. 9, directing pilot pressure to port *A* of valve No. 3. This valve initiates the second half of the cycle, the reversal of the work pistons.

Pilot pressure moves the piston of valve No. 3 to the right, exhausting the *X* and *Y* ports of valve No. 7 and directing working pressure to port *U* of time-delay valve No. 7. This valve regulates the length of time that the work pistons dwell in their extended positions. After this adjustable dwell period, valve No. 7 acts to open port *V* to port *Y*, admitting pilot pressure to port *D* of valve No. 5. When this happens, the piston of valve No. 5 shifts to the right. Pump supply is now directed through port *O* of this valve to the ends of the ram cylinders and to port AA of valve No. 25. The rams of both cylinders retract.

At the end of their upstroke, the trip bars carried by the rams depress the plungers of valves Nos. 25 and 26 to the position shown in the diagram. The oil under pressure at port *AA* moves through port *BB* of valve No. 25; then, through valve No. 26 to the fluid motor and port *AA* of valve No. 17.

The plunger of valve No. 17—which is the lock plunger—withdraws, allowing the fluid motor to withdraw the index cam and the cam shaft. The latter carries the operating cams for valves Nos. 1 and 2. As the table indexes to the next position, the piston of valve No. 2 is released, connecting the oil pressure at port *P*, through port R to the pilot chamber of valve No. 3. The piston of this valve moves down to the position shown.

Note that no pressure is available at port *S* of valve No. 3. Pressure for this port must be supplied from port

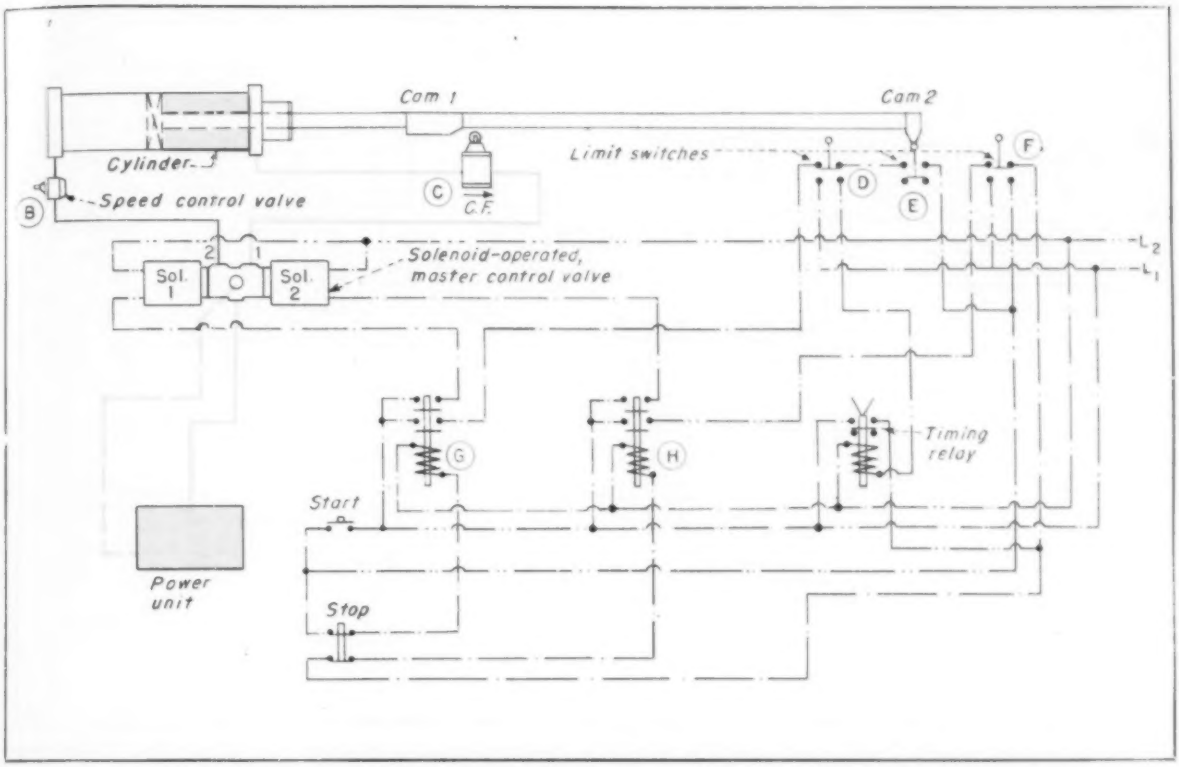


Fig. 5—Simple emergency stop is provided by this machine circuit. Work cylinder is powered hydraulically, but control is electrical. If it is necessary to halt operation of the machine at any point in the cycle, the operator pushes the stop button. This action opens the energizing circuits of both magnetic contactors. Stoppage is instantaneous.

BB of valve No. 7, which is blocked when the lock plunger is retracted.

The second operating cam momentarily closes, then overrides valve No. 1, applying pilot pressure from port *F*, through port G to the pilot chamber J of valve No. 4. The piston of this valve shifts, completing the cycle and bypassing the pump output back to the tank through port *M*.

If the handle of valve No. 13 is latched in the start position, valve No. 1 is inoperative. Therefore, pilot pressure cannot be applied at pilot chamber J of valve No. 4. Instead, pilot pressure is directed to chamber *K* through port *SS* of valve No. 13. The cycle is then automatically repeated when the piston of valve No. 2 is depressed by the operating cam.

ELECTRICAL CONTROLS. Using the circuit shown in Fig. 5, movement of the work piston can be stopped at any time during the cycle. In case of emergency, the operator pushes the "stop" button, thus opening the energizing circuits of both magnetic contactors. This is one of the simplest safety circuits and is applicable where an emergency stop feature is considered an adequate safety provision.

To begin the cycle, the operator depresses the "start" button until action of the piston moves cam No. 2 away from limit switch *E*. The latter, which is normally closed, complete the circuit to the coil of contactor *G* through a second normally closed limit switch *D*. Solenoid No. 1 of the master valve is thereby energized, causing oil to flow through port No. 1 to the rod end of the cylinder. The master valve is three-position, four way and is double-solenoil operated. The valve has a spring return to neutral In the neutral position, both cylinder ports are blocked and pump bypassed to the tank. The piston retracts slowly as oil is metered from the blind end of the cylinder through B, a speed control valve.

When cam No. 2 contacts the limit switch *D*, the circuit to contactor *G* is broken. This deenergizes solenoid No. 1 and the cylinder stops. Simultaneously, the throwing of limit switch *D* starts the timing relay. The latter contains a pneumatic dashpot that allows the relay contacts to close after a delay. This time delay is adjustable between 0.2 sec and three minutes after energization.

After the preset period of time elapses, the relay contacts close the circuit to contactor H, energizing solenoid No. 2. The contactor is held closed through the normally-closed limit switch F. The work piston advances rapidly until cam No. 1 depresses the plunger of the second speed control valve C. This valve then acts as a metering device to slow piston movement to a preset rate for the remainder of the stroke.

When cam No. 2 actuates the limit switch *F*, the circuit to contactor *H* is broken and a circuit to contactor *G* is closed. Solenoid No. 2 then is cut off and solenoid No. 1 is energized. The piston now retracts until cam No. 2 trips limit switch E. This breaks the circuit to contactor G, deenergizing solenoid No. 1 and stopping the work piston.

ELECTRICAL INTERLOCKS. As stated, the circuit of Fig. 5 features only emergency stop. However, the use of electrical controls also makes possible the application of interlocking schemes for safety. In fact, safety measures are usually more easily provided with electrical controls than with 100 percent hydraulic operation. It is simpler to wire a switch than to couple a valve.

As an illustration, consider the press circuit in Fig. 6.

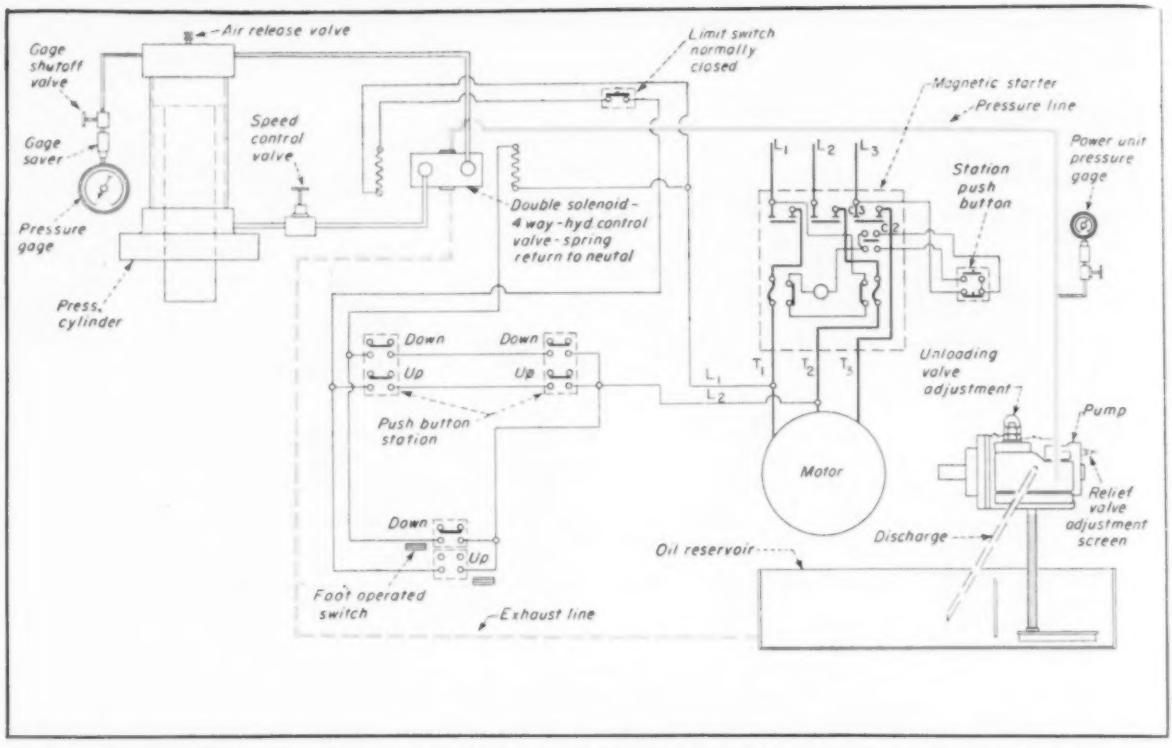


Fig. 6—Electrical control of hydraulic circuits simplifies the task of interlocking machine functions. Such interlocking is commonly required for machine safety. Limit switches, relays and pushbuttons are widely employed to provide interlocks.

To start the down stroke of the ram, the buttons marked "down" on both pushbutton stations must be held in. This throws the solenoid control valve into starting position. The ram travels down rapidly at large volume and nominal pressure until it meets the work. After meeting the work, the pressure builds up. The ram continues to move down at small volume until the ram reaches its maximum tonnage setting and stops. At this point, the operation is complete.

To operate the return stroke of the ram, the hold buttons marked "up" on each push button station must be held in. This throws the solenoid control valve into reverse position. The ram travels up rapidly at large volume and nominal pressure until the movable platen meets a collar on the trip rod which then contacts a normally closed limit switch. This breaks the circuit. The ram stops and the control valve is thrown into neutral position, thus blocking all cylinder ports and permitting the oil to flow freely from pump to tank.

Upon release of either/or both buttons on the "down" or "up" stroke, the circuit is broken and the ram stops. This also throws the solenoid control valve into neutral position, blocking all cylinder ports and permitting the oil to flow freely from pump to tank.

The length of return stroke is adjustable, from minimum up to maximum, by means of the stop collar on the trip rod. By limiting the length of the return stroke, unnecessary ram travel is avoided.

Deliveries of both pumps are available to the hydraulic circuit until the working pressure builds up to the point exceeding the setting of the adjustable spring closed unloading valve. The pressure build-up opens the unloading valve, which, in turn, allows the delivery of the large pump to recirculate back to the tank without restriction. Meantime, the smaller pump working alone supplies oil to the hydraulic system. Working pressure as developed by the smaller pump is limited by the integral relief valve setting.

The unloading valve and the relief valve may be adjusted to meet any set of pressure working ranges. Setting of the unloading valve should be such that it will not open until a working pressure slightly higher than the maximum required for rapid action is built up. The relief valve setting must be equal to or slightly higher than the pressure required for the slower action. There must be a minimum differential of approximately 150 psi between the unloading valve setting and the relief valve setting.

A hand-wheel hydraulic valve is set in the lower line of the cylinder and is used for control of down speed of ram. The power unit gage is used only when making a pressure adjustment or checking line pressure. The press gage is used only when checking ram tonnage. A gage shut off valve is provided with each gage in order to relieve wear on the sensitive parts of the gage by keeping the gage lines closed except when checking or adjusting pressure.

In all-hydraulic machines, complex interlocks are required to insure safety of machine and personnel. This fact is illustrated by Fig. 7, showing the operating circuit for the index table and work cylinder of an industrial machine. This design provides emergency shutdown, coordinates piston movement with table indexing and prevents damage to mechanism caused by jamming of the table.

Under the conditions shown in Fig. 7, the machine is idle with the emergency valve No. 12 in the run position and the operating valve No. 13 in stop position. The cam-operated valves Nos. 1 and 2 are both released, while valve No. 11 is depressed.

Operating pressure from the hydraulic pump is directed to the inlets of valves Nos. 4 and 12. Passing through port *S* of the latter, oil reaches the inlet of valve No. 13, then

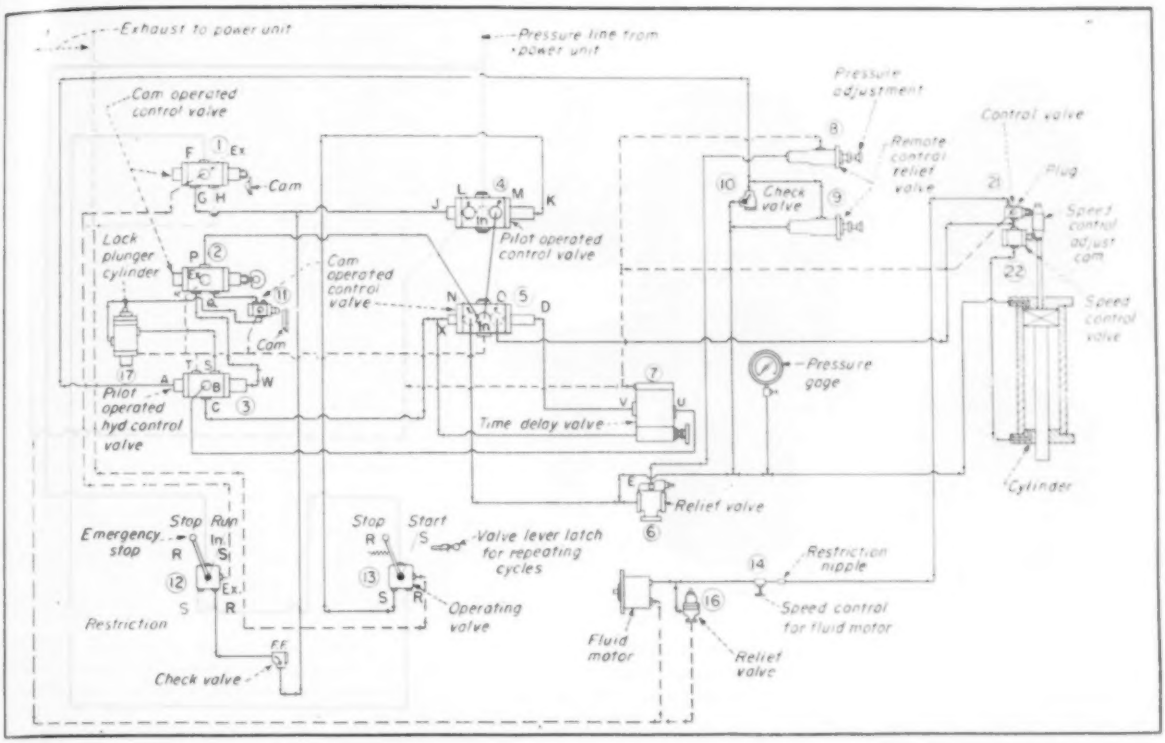


Fig. 7—**The various operations in all-hydraulic machines can be interlocked. A method frequently employed makes use of cam-operated valves to provide the necessary coordination of machine movements such as that of the indexing fluid motor.**

flows out port R through the restriction nipple to the inlet of valve No. 1. Since this valve is in the released position, the pump delivery is directed out port *H* to the tank. The piston of valve No. 4 is to the right so that the pump delivery is being returned to sump via port L of this valve.

For single index operation, the emergency stop valve is placed in the start position. The operator shifts valve No. 13 to the start position, then releases the handle, which is spring-returned to the stop location.

Hydraulic pressure at the inlet of valve No. 13 is directed momentarily to pilot chamber *K* of valve No. 4 shifting its piston to the left. Oil is now delivered out port *M* of valve No. 4 to the inlet of valve No. 5. Since the piston of the latter is to the right, oil moves from port *N* of valve No. 5 to the blind end of the cylinder. The ram advances under the pressure set by relief valve No. 6. This valve is remotely controlled by valve No. 8. When the pressure to the blind end of the cylinder reaches its maximum, oil opens the adjustable valve No. 9 and flows to pilot connection A of valve No. 3, moving the piston of this valve to the right.

Pressure from the inlet port of valve No. 5 flows through valves Nos. 2 and 11 and through the lock plunger cylinder to port *S* of valve No. 3. Valve 11 is in the depressed position and the lock plunger is in the engaged position. Oil then flows from port B of valve No. 3 to port *U* of adjustable time delay valve No. 7. After a delay, oil is directed from port *V* of valve No. 7 to port *D* of valve No. 5. The piston of the latter moves to the left sending oil through the speed control valve No. 22 to the lower end of the ram cylinder. The ram begins to rise.

Valve No. 22 controls the speed of the downstroke by metering the exhaust flow of oil when the plunger is depressed. Free oil flow for fast ram upstroke is possible even when cam and roller are in contact, because a check valve is built into the speed control valve.

TABLE INDEXING. When the ram in Fig. 7 reaches the end of the upstroke, the cam roller of valve No. 21 is depressed. Then, oil is admitted to the fluid motor, turning the worktable and the valve cam shaft. Relief valve No. 16 is provided to adjust the maximum pressure to the fluid motor, so that the table may be stalled safely against any obstructions. As soon as the cam shaft starts turning, the plunger of valve No. 2 is depressed. Pressure from the inlet of valve No. 5 is now directed through port *R* of valve No. 2 to the pilot connection of valve No. 3. The piston of this valve moves to the left. Then, the index lock plunger retracts.

After an 180 deg index movement of the table, the cam mounted on the table depresses the roller of valve No. 11 and the cam on the cam shaft releases the roller of valve No. 2. This directs oil from port Q of valve No. 2, through valve No. 11 to the lock plunger cylinder. Action of the plunger again locks the table. The cam on the index table also momentarily depresses the roller of valve No. 1, applying pilot pressure out port G of this valve to pilot chamber J of valve No. 4. The piston of the latter shifts to the right, removing all pressure from the circuit and stopping all action. The pump supply returns to the tank through port *L* of valve No. 4 and port *H* of valve No. 1. The roller of the latter has been released by its roller.

For continuous operation, the handle of valve No. 13 is latched in the run position. Oil pressure from port *S* of this valve is maintained on pilot connection *K* of valve No. 4. This valve, therefore, remains in the running position. Valve No. 1 is now ineffective.

For emergency shut-off, valve No. 12 is moved to the stop position. Pilot pressure from the power unit flows from port *R* of valve No. 12 directly to pilot connection *J* of valve No. 4. The piston of this valve moves to the right, shutting off the oil supply and by-passing it through port *L* to tank.

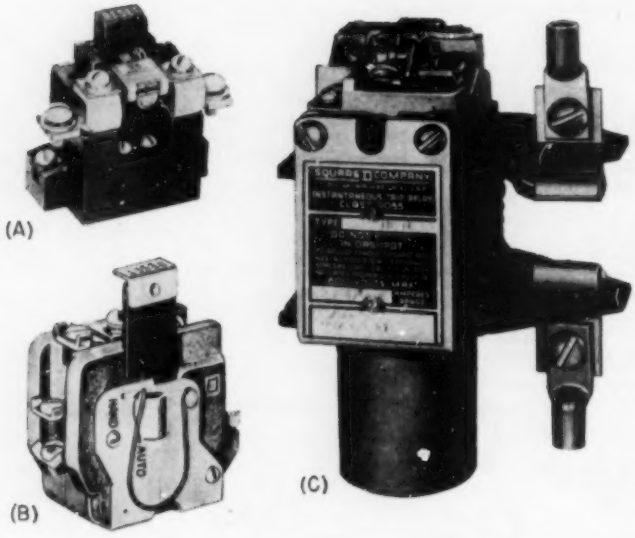


Fig. 1—Overload or motor-running protective devices. (A) Melting alloy type overload relay. Relay contacts are opened when alloy melts. (B) Bimetallic thermal overload relay. (C) Magnetic overload relay.

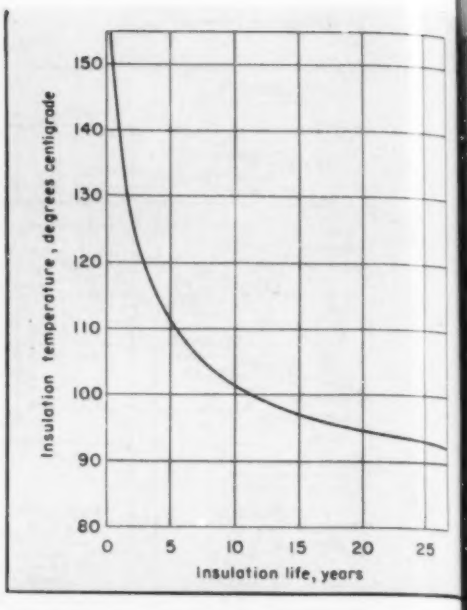


Fig. 2—Optimum relationship between insulation life and temperature. Effects of abrasion, moisture, corrosion and mechanical stresses are excluded.

Overload Relays For Motor Protection

L. E. DAEHLER
Special Control Section, Square D Company

COMMON USAGE accepts the term "overload" to designate a condition of mechanical load imposed on a motor that results in currents greater than the full load current but not greater than the current with locked rotor. The term "overcurrent" is sometimes used also to describe this condition. But more properly "overcurrent" is confined to excessive motor currents caused by short circuits and grounds.

In d-c motor applications, "overtorque" is frequently used to describe a load condition that would result in the motor carrying a current that exceeds the limit of the safe commutation capacity, or a stalled condition.

In brief, the steps in the procedure of providing a motor with overload protection are: (1) Analyze the normal motor load; (2) Determine what conditions of unusual overload are likely to be encountered; (3) Apply these data to select the type of overload relay most suited to the conditions; and (4) Select the proper size of thermal unit or current coil that will protect the motor and yet allow maximum utilization of the motor capacity.

Any general guide to the selection and application of overload relays must be based on the assumption that the motor performance characteristics are matched to the mechanical load normally imposed on the motor. The problem of proper overload protection then resolves into one of allowing full utilization of the capacity of the motor and concurrently protecting the motor from the effects of unusual conditions of overload. The function of the overload relay is to differentiate between those overloads that are harmful to the motor, and sometimes to the driven machine, and those that are not.

The more that the engineer knows about the motor operating conditions, and the more that he applies such knowledge in making relay selection an optimum, obviously, the greater will be the utilization of the motor's capacity. The most effective method of obtaining such data is to conduct tests.

The capacity of a given electric motor to do work without injury to itself, in general, is determined by the amount of internal heat it is able to dissipate. This heat is produced by the motor core losses (hysteresis and eddy current), the bearing friction, and the resistance offered by the windings or "copper loss." The combined effect of these losses causes the motor temperature to rise until the rate of dissipating heat equals the rate of producing heat.

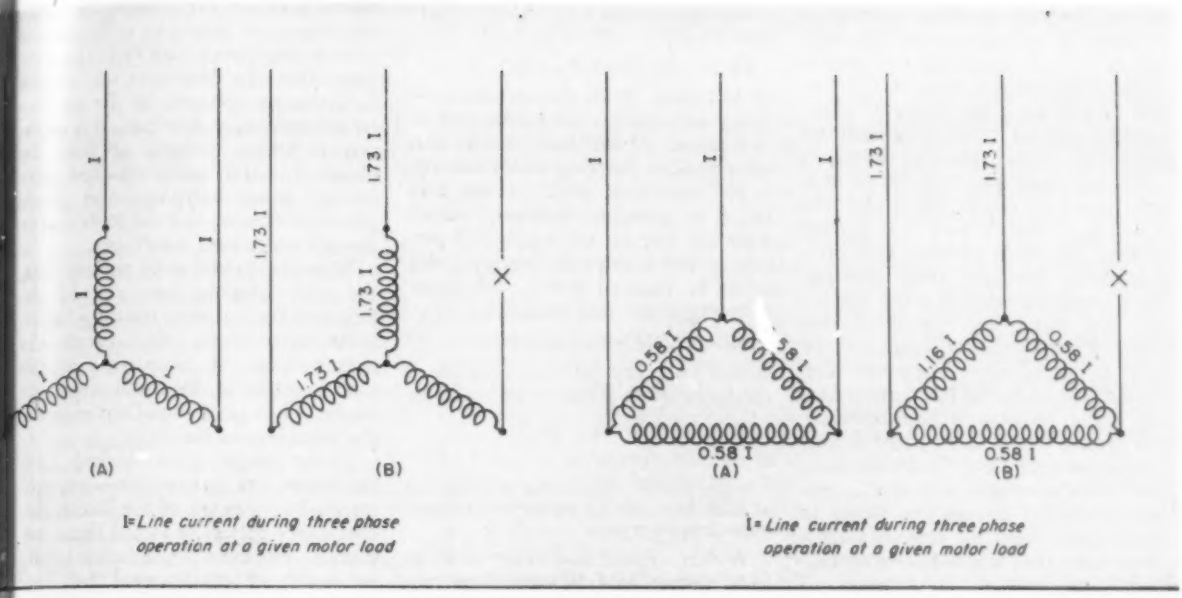


Fig. 3—Line current and phase winding currents in a wye connected motor. (A) Polyphase operation. (B) Single phase operation. Line and winding currents increase 73 percent.

Fig. 4—Line current and phase winding currents in a delta connected motor. (A) Polyphase operation. (B) Single phase operation. Line current divides 2 to 1 through the windings.

Problems of protecting motors under conditions of excessive mechanical load, fluctuating load, locked rotor, single phasing in secondary circuit, and open lead in transformer primary circuit. Characteristics of the basic types of thermal overload relays and magnetic overload relays and their applications. Selection of type and size that permits maximum utilization of the motor capacity.

Since the insulation is more susceptible to deterioration from high temperatures than is any other material used in motor construction, motor manufacturers establish certain limits of operating temperature to conserve the life of the insulation. The curve shown in Fig. 2 gives some data on the relative effect of temperature upon insulation life.

In a motor, the core and bearing losses are relatively constant and are a small percentage of the total losses. The copper loss is proportional to the torque load on the motor. This loss is so large a percentage of the total loss that a measure of the electrical current that produces the copper loss is also a proportionate measure of the motor temperature under normal conditions of ventilation. This principle is the basis for the design of current-operated overload relays.

Problems of Protecting Motors From Unusual Overloads

EXCESSIVE MECHANICAL LOAD. Usually no injury to the motor results from mechanical loads greater than normal when imposed for a relatively short time and they do not exceed the stalling torque of the motor. When a mechanical overload is imposed for an appreciable time, however, overload relays should function before excessive current causes the motor temperature to reach a value that would materially shorten insulation life.

Where the mechanical load varies between wide limits, or is pulsating in nature, the problem of selecting the proper size motor and overload relay should be approached by a root-mean-square analysis of motor current.

SINGLE PHASE OPERATION CAUSED BY OPEN SECONDARY CIRCUIT. Several considerations are associated with an analysis of the amount of protection afforded to three phase motors by the overload relay when the motor is operating under single phase.

In a wye connected motor during single phasing, Fig. 3 (B), two phases of the motor winding are active. Both of these windings carry 100 percent of the line current. For equal motor loads, during single phasing the line current is approximately 173 percent of the line current during three phase operation (neglecting change in power factor). Thus an overload relay rated at 115 percent of full load line current affords normal protection.

In three-phase operation, the phase currents in a delta connected motor, Fig. 4 (A), are approximately 58 percent of the line current, therefore,

each of the phase windings is designed to carry 58 percent of the full load line current. If the motor can operate continuously without harm at 115 percent of full load, the allowable phase winding current would be about 67 percent of the full load line current.

During single phase operation of a delta connected motor, Fig. 4 (B), the line current divides in a 2 to 1 ratio through the motor phases. This division results from one phase winding being connected directly across the active line phase and the other two phase windings being connected in series across the active line phase. For equal motor loads, the line current during single phasing is approximately 173 percent of the line current during three phase operation. Thus with overload relays selected to trip at 115 percent of normal current, the motor is disconnected from the line in a relatively short time when delivering full load.

The problem, however, is to determine if a range of motor loading exists that will result in a line current value lower than that required to trip the overload relays, yet at the same time allow a current in excess of 67 percent of the full load polyphase line current to exist in the direct connected phase winding. When the current in the direct connected-phase winding equals 67 percent, the current through each of the two motor phase windings connected in series is 33.5 percent, thus the line current would be

$$67 + 33.5 = 100.5 \text{ percent}$$

of the polyphase full load line current.

A line current of 100.5 percent would result from a motor load of approximately

$$100.5 \times 100/173 = 58 \text{ percent}$$

of full load. With this condition existing and the overload relays set at 115 percent of full load current, it is quite possible that they would not trip.

The maximum point of the load range in question, obviously, occurs when the line current equals 115 percent, at which point the overload relay would be expected to trip. The corresponding motor load would be

$$115 \times 100/173 = 66.5 \text{ percent}$$

of full load, and the maximum phase winding current at this point would be

$$115 \times 2/3 = 76.5 \text{ percent}$$

of the line current, or

$$76.5 \times 100/58 = 132 \text{ percent}$$

of the normal full load value and 115 percent of its maximum allowable rating.

Within a motor load range of 58 to 66.5 percent of full load, therefore, the protection afforded by an overload relay for the delta connected motor may be considered doubtful under the conditions stated. On the other hand, if the normal motor load is equal to full load, there would be only a remote probability of the normal load being in the 58 to 66.5 percent range at a time coincident with the single phasing. For applications where the normal load is below full load, therefore, it is good practice to select the overload relays in accordance with the line current at normal load rather than the rated full load current.

LOCKED ROTOR CONDITIONS. Another consideration is protection when the motor fails to start. Such an event might even be caused by a mechanical fault of the driven load or by a single phase line. To determine the amount of protection afforded by the particular overload relays involved, it is necessary to know: Length of time the motor can safely endure locked rotor current under polyphase and single phase conditions; and the locked rotor current under both conditions.

With the locked rotor current data, the relay tripping time can be determined from a curve showing the relationship between relay current and tripping time. A comparison of this time with that of the motor endurance under locked rotor conditions indicates the suitability of the relay.

Under single phase locked rotor conditions, the line current is approximately 86.5 percent of the inrush current under polyphase locked rotor conditions. For example, a motor having an inrush of 600 percent full load current on polyphase service has an inrush of 520 percent of full load current on single phase service. This lower current, of course, increases the relay tripping time, therefore, a comparison should again be made with motor-endurance time corresponding to single phase locked rotor conditions.

It is interesting to note that for a wye connected motor, during single phasing the current through each of the two active phase windings is 86.5 percent of the polyphase locked rotor current. But for a delta connected motor, however, in the one phase winding that is connected directly across the line the current is the same as it would be under polyphase locked

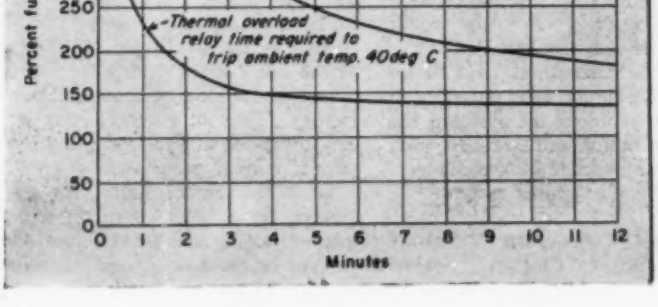


Fig. 5—Comparative motor heating and thermal overload relay operating characteristics. Characteristics of both curves are similar.

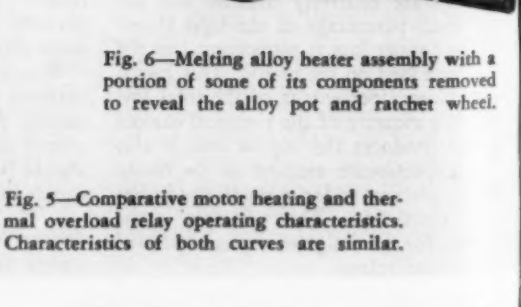


Fig. 6—Melting alloy heater assembly with a portion of some of its components removed to reveal the alloy pot and ratchet wheel.

rotor conditions. This consideration is important since as a result of a lower percentage of line current the relay tripping time is longer under single phase conditions. The current flowing through the two motor phases connected in series is one-half that carried by the phase winding connected directly across the line.

SINGLE PHASE OPERATION Caused by Open Circuit in Transformer Primary. Of special interest is an open circuit on the primary or high voltage side of a wye-delta or a delta-wye connected three phase transformer bank with an isolated or ungrounded neutral. In this event, the current in one secondary line rises to approximately two times the current value in the other two secondary lines. Based on the probability of such a fault occurring, and also on the probability of it being in a particular primary line such that the greater value of current flows in the secondary line not provided with an overload relay, the use of three overload relays instead of the usual two is indicated for complete protection.

From the standpoint of economy, an analysis of each application should be made. In such an analysis, the additional cost of the overload relay is weighted against such factors as the motor cost and the known reliability of power service at the particular location. Relative to the reliability of power service, a greater possibility of the fault occurring exists when the primary side of the transformer bank is protected by fuses rather than a single circuit breaker.

Basic Types of Overload Relays and Their Applications

Current operated overload relays are of two general types: Thermal overload relays; and Magnetic overload relays. They derive their names from the method by which each utilizes the motor currents to perform the protective function.

Thermal overload relays, rather than the magnetic type overload relays, are applied in the majority of ordinary motor installations. There are several reasons for this practice. Primarily, the tripping characteristics of the thermal device offer adequate protection during conditions of unusual motor overload at a minimum of initial cost and of maintenance expense. Reliability in operation, simplicity of design, adaptability both physically and electrically to standard contactors, and convenience in selecting and installing the interchangeable heater elements are other factors that contribute to the general use of the thermal overload relay.

Basically, the problem of thermal relay design is to create a device with a thermal capacity resembling the heat temperature characteristic of the motor, and thereby duplicate a proportionate value of the actual motor temperature.

A graphic comparison of the thermal characteristics of a motor and a thermal overload relay is shown in Fig. 5. The portion of the motor heating curve shown represents the time required in minutes to reach a temperature of 55 deg C above ambient for various load percentage values greater than full load. The lower curve represents the time required by the thermal overload to trip. Note the general similarity in the curve characteristics.

There are two general designs of the thermal overload relay: Melting alloy type; and the Bimetallic type.

A melting alloy relay assembly is shown in Fig. 1 (A). The alloy pot and ratchet wheel are shown in the sectional view Fig. 6 of the heater element. The relay contacts are opened by a pre-set spring operated mechanism, which is released when the alloy melts. The contacts are reset after the alloy solidifies, at which time the ratchet wheel is not free to rotate until the alloy melts again.

Two advantages are obtained by combining the heater element and the alloy pot in one assembly: (1) If the heater element burns out, or if the ratchet wheel is damaged, the entire assembly can be conveniently replaced by a new one of proven reliability and calibration; and (2) the heater element is securely clamped in a fixed position with respect to the alloy pot. Variations in the relay performance as a result of distortion of the heater element or misalignment with the alloy pot are thus avoided.

Melting alloy type relays are available in sizes having nominal ratings in a range from 25 to 300 amp. For currents in excess of this range, or where mounting space limitation preclude the use of the larger sizes, ratio current transformers can be employed.

The suitability of the standard thermal type overload relay for a given application can be determined from a study of tripping characteristic curves similar to those shown in Fig. 7. Such curves give the relationship between the motor current (expressed in percentage of a particular relay heater element rating) and the tripping time for various relay sizes.

The shaded portions of the curves represent the variation of tripping time of the different size heater elements of a particular type, rather than the variation in any one particular size. For the curves shown in Fig. 7, the temperature reference or starting point for the heater element is that of the relay at the ambient temperature or "cold."

Such curves help solve most of the problems concerned with the "conditions of unusual overload" discussed in the preceding paragraphs.

Suppose, for example, for a certain application it is desirable to investigate the protection that melting-alloy relays offer under single phase locked rotor conditions. The motor manufacturer

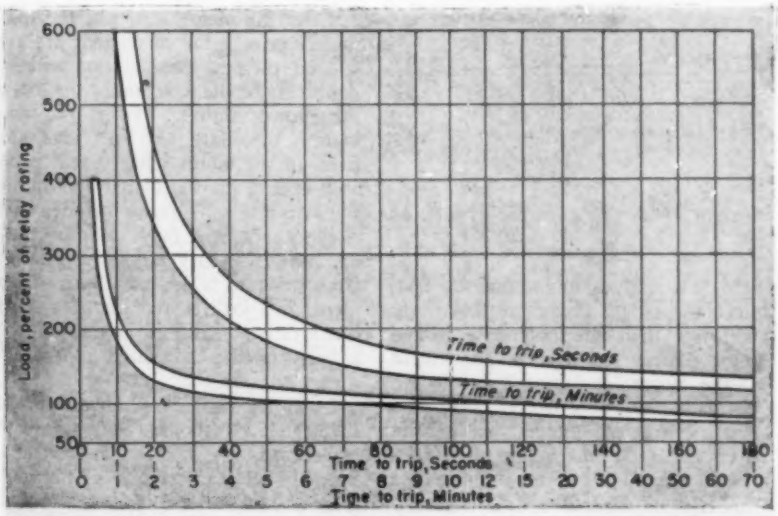


Fig. 7—Range of trip time at various overloads for one type of standard thermal overload relay when it is enclosed in a size 4 starter at 40 C ambient.

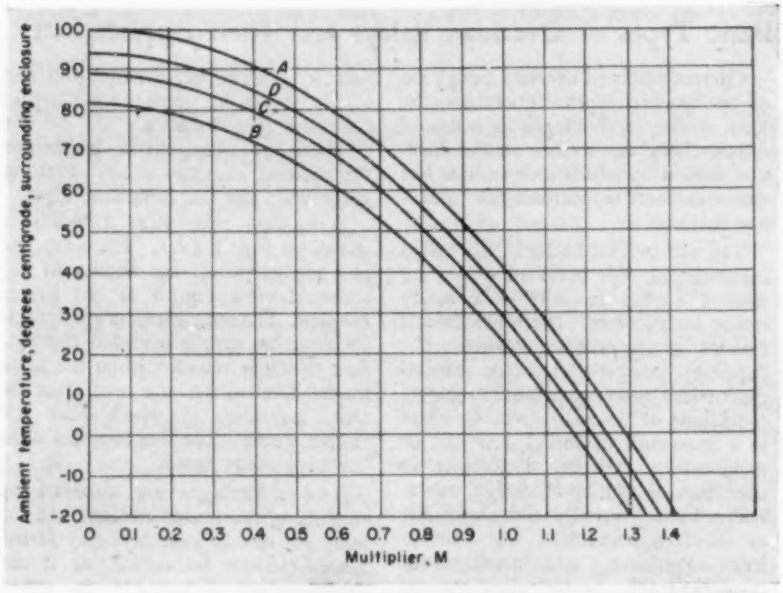
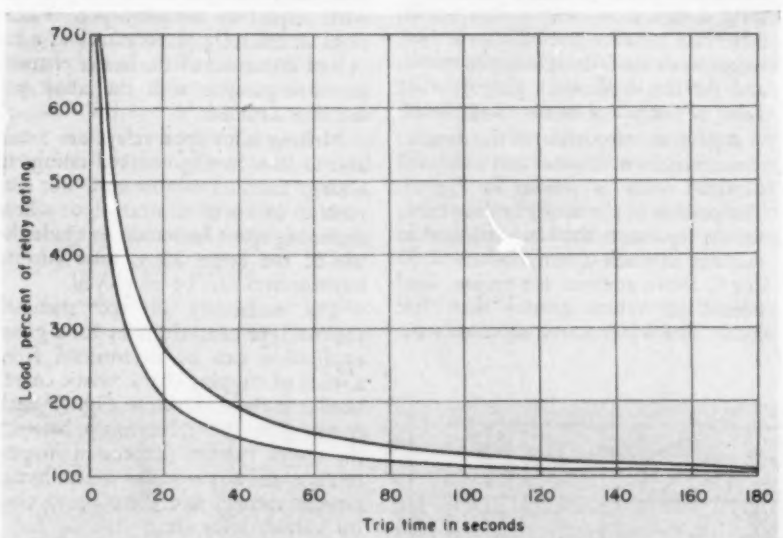


Fig. 8 (Above)—Effect of ambient temperature change on the tripping characteristics of melting alloy relays. Fig. 9 (Below)—Trip-time characteristic of a 50 amp rated quick-trip thermal overload relay in open air.



has supplied the following data: Full load current, 10 amp; polyphase locked rotor current, 58 amp; length of time motor can endure polyphase locked rotor, 32 seconds; and motor connections, delta. Assume that the single phase condition results from some fault in the secondary circuit of the supplying transformers. A size 1 starter, equipped with melting alloy units rated at 12.8 amp, operating at an ambient temperature of 40 C is under consideration.

The inrush current, as indicated in a preceding paragraph under single phase locked rotor conditions, is 86.5 percent of the polyphase locked rotor current, or in this example a value of

$0.865 \times 58 = 50$ amp.

A first analysis might indicate that, since the single phase inrush current is lower than the polyphase locked rotor current, an upward adjustment of the motor "endurance" time could be made. Note, however, that in a delta connected motor the percent overload of the one motor phase connected directly across the single phase line is equal to the same percent overload under polyphase locked rotor conditions. Thus the time of 32 seconds is the correct limiting factor.

To determine the relay tripping time from Fig. 7, first find the percent ratio of the inrush current to the ampere rating of the relay, or

$50 \times 100/12.8 = 391$ percent.

Then obtain the tripping time for that ratio from a trip time curve. For 391 percent, the curve of Fig. 7 indicates a tripping time of 15 to 23 seconds. Since the motor manufacturer's recommendation is 32 seconds, it can be concluded that protection is afforded the motor under the conditions stated.

RELAYS FOR FLUCTUATING LOADS. In the selection of relays for applications where the normal load varies through a wide range of values above and below full load, an analysis of the protection afforded by melting alloy relays may be complex.

The safest approach, of course, is in knowing first by test that the motor will not overheat under the conditions of load imposed upon it, and then selecting a thermal unit, also by test, that will allow this load yet will trip on any higher value. It is possible the final selection will not agree with that derived from standard selection tables on the basis of motor full load current. Should a larger size be indicated by the test, some sacrifice must be expected in the protection afforded under locked rotor and single phase conditions.

Where a heater element size must be selected in advance of the installation, the best approach is through an analysis of the predicted root-mean-square current. Since the motor rating probably will also be selected on the same basis, the two studies can be made concurrently.

After the motor load and the root-mean-square value of current are calculated, the first consideration will undoubtedly be the selection of the motor horsepower rating. To allow some margin of safety, the full load amperes of the motor selected will probably exceed the calculated root-mean-square value of current. Under such circumstances, the overload relay thermal unit size may either be selected from standard tables on a basis of the motor full load current or, if a more conservative selection is desired, on a basis of the calculated root-mean-square current.

In either procedure, however, one further check should be made with respect to the selected heater size. Even though a calculation of the root-mean-square current involves the total time of the particular duty cycle imposed on the motor, certain portions of the curve may exist where the root-mean-square value exceeds the rating

the heater unit with respect to the tripping time. An example is a duty cycle having relatively long "idle" periods in between high peaks. Although by utilization of the next "idle" period for cooling, the motor will probably carry the maximum value of root-mean-square current without damage to the windings, once the alloy melting temperature is reached the overload relay will trip and thus no advantage can be taken of the next low current period.

The root-mean-square current for such maximum portions of the duty cycle, therefore, must be calculated separately to determine if the tripping time of the relay selected exceeds the time interval corresponding to the root-mean-square current value of the maximum portion of the duty cycle. The relay tripping time is derived from characteristic curves, such as Fig. 7. If the heater element tripping time is found to be less than the duty cycle time interval, the next larger size heater should be considered.

When a heater size must be employed that is larger than would ordinarily be selected on the basis of full load motor current, it is important to note that some measure of protection under locked rotor or single phase conditions is sacrificed.

INFLUENCE OF AMBIENT TEMPERATURE. Under conditions where the motor and controller are located in the same ambient temperature, proper protection of the motor will be maintained by using heater elements recommended by standard selection tables, regardless of temperature.

The basic calibration of thermal overload relay units is sometimes made with the unit mounted on a test board in open air at an ambient temperature of 40 C. When the melting alloy relay is mounted on a motor starter and the starter is placed in an enclosure, however, a different value of tripping current may be expected as the result of a higher air temperature within the enclosure. The effect of ambient temperature change on the tripping characteristic of melting alloy relays is shown in Fig. 8. Curve *A* is for a relay mounted on a test board with access to the open air. Note that for this curve at an ambient temperature of 40 C, the multiplier or temperature factor is unity. The assigned ampere rating of the thermal heater unit, therefore, is the current at which the relay will ultimately trip at 40 C in open air. Curves *B*, *C*, and *D* show the same relationship except with the overload relay mounted on various sizes of enclosed starters.

To calculate the ultimate tripping current at an ambient temperature other than 40 C, the following formula can be used.

Where

I_u = ultimate tripping current, amp
M = multiplier taken from Fig. 8
I_r = rating of thermal heater unit at 40 C in open air, amp
$I_u = MI_r$

At ambient temperatures higher than 40 C, the time required for the thermal overload relay to trip decreases. Thus a closer degree of protection is afforded when the overload relay and motor are both at the same high ambient temperature. This is an advantage since the actual motor temperature is correspondingly higher, and even though the guaranteed temperature rise of the motor might not be exceeded, the motor has less reserve capacity to sustain an overload. Conversely, the motor has greater overload reserve at low ambient temperatures, utilization of which is allowed by the thermal overload relay because its tripping time is longer.

When it is not possible to operate the motor and overload relay at the same ambient temperature, a change in size of heater units may be indicated to compensate for the difference. If the motor ambient temperature is higher than the controller, a smaller size overload relay than normal should be selected. When the reverse situation with respect to ambient temperature is true, it is not necessary to make allowance for the temperature difference from a standpoint of motor protection, but rather to permit full output of the motor. Thus an overload relay unit size larger than normal would be indicated.

Another temperature factor relating to the proper selection of melting alloy thermal units is concerned with the allowable temperature rise of the motor. Since the majority of motors are of the open type with a 40 deg C temperature rise, heater unit selection tables are usually based on this type. Semi-enclosed and totally-enclosed fan-cooled motors, however, have a higher temperature rise, usually 50 deg C to 55 deg C respectively, and because of this rating have little or no continuous overload capacity. Therefore, a smaller size heater unit than listed for the 40 deg C is recommended for the 50 and 55 deg C motors.

To increase the versatility of the melting alloy relay and expand its range of applications, "quick-trip" heater units have been developed. Quick-trip units are frequently used to protect motors having a relatively low inrush current and where the standard heater element would not trip in sufficient time under locked rotor conditions.

The trip time characteristic of one 50 amp rated quick-trip unit mounted on a test board in the open air is shown in Fig. 9. This type element is designed for applications where the temperature characteristic of the motor involved is more critical than that of the standard motor. This condition may result from one of several reasons. A motor with a low starting current, for example, might not have sufficient protection with a standard melting alloy heater unit under locked rotor conditions, particularly when the inrush current ranges between 300 and 350 percent of the full load current.

In the same category are intermittently rated torque motors that frequently operate with the rotor locked. Protection for this condition is thus of principal importance. Intermittently rated, or "short-time" motors also provide a field for application of quick-trip heater elements. The quick-trip elements also are of value in protecting sealed (hermetic type) refrigeration compressor motors where the conditions of application are frequently such that the ratio of locked rotor current to running current is quite low.

"Long-time" heater units also have been developed for melting alloy type relays. Principal application of these heater units is for the protection of motors driving centrifugal machinery or wherever a relatively long period of motor accelerating time is involved. A characteristic trip time curve is shown in Fig. 10. A comparison of this curve with that of the standard heater unit will indicate the additional time allowed before tripping.

To apply the "long-time" thermal unit, a detailed study must first be made of the motor load, including the longest accelerating time and the conditions of greatest overloads. In such an analysis, the same methods are used as previously indicated for fluctuating loads, with the objective of selecting a size that will allow the normal load without motor overheating yet trip on load conditions above this point.

In selecting a "long-time" melting alloy heater unit, special consideration must be given to conditions of locked rotor. Knowledge of the motor's endurance time under this condition is necessary to make a comparison with the relay tripping time. The latter can be obtained by applying to a curve like that of Fig. 10 the ratio (expressed in percent) of inrush current to the ampere rating of a particular size heater unit. Where the relay tripping time exceeds that of the motor endurance under locked rotor conditions, evidently either the con-

dition of partial protection must be accepted or a compromise made that lowers the motor output by the overload relay.

Applications involving extremely long accelerating times are occasionally encountered where the "long-time" relay tripping characteristic is not sufficient to allow the load requirements. In such events, the solution usually is a saturated core current transformer used in conjunction with a standard unit.

The basic operating principle of the saturated core transformer is that of causing a non-linear relationship to exist between the primary and secondary transformer currents. This relationship is obtained by loading the secondary (insertion of resistance) to such an extent that insufficient flux is produced by the ampere turns in the primary to produce an equivalent number of ampere turns in the secondary. This relationship is indicated in Fig. 11. Note that up to 100 percent of the relay rating, the ratio of line current to relay current is approximately the same; whereas above this point the divergence increases rapidly. Experience has indicated that different degrees of saturation are desirable, depending upon the particular application involved.

Bimetallic Type Thermal Overload Relay

A bimetallic thermal overload relay in the "open" position is shown in the sectional view Fig. 12. Actuation of the relay contact is accomplished by the outward expansion of the U-shaped bimetallic strip. Heat is supplied from a current calibrated heater element. In Fig. 12 the heater element follows the inside contour of the bimetallic strip.

By changing the setting of the screw on the right-hand side of the relay, the normal trip current rating of the heater element can be adjusted through a range from 85 to 115 percent. The relay can be reset either by hand or automatically. Bimetallic overload relays are available in nominal ratings ranging from 25 to 150 amperes.

Several, advantages are offered by the bimetallic overload relay for certain applications. One is the automatic reset feature. In the event of an installation shutdown where the motor controller is distant from the machine operator, as soon as the relay resets, the automatic reset feature allows the operator to restart the motor without moving from his pushbutton control station. It is always advisable, however, to use the automatic reset feature only with three wire control, that is, where the motor control circuit is established by a momentary contact push button or control device. With two wire control accessories, such as float or pressure switches, the bimetallic relay should be adjusted for manual reset.

Another design feature of the bimetallic overload relay is the means to adjust conveniently the current rating at which the relay will ultimately trip. Settings above the 100 percent rating, however, should be examined closely with respect to the final motor temperature.

As with the melting alloy relay, the mounting of the bimetallic device on an enclosed starter lowers the ultimate tripping point with respect to the "open" rating.

Magnetic Overload Relays

TIME LIMIT MAGNETIC OVERLOAD RELAY. A current-operated overload device of this type is shown in Fig. 1 (C). Its important parts are a current coil, a contact block, and an oil dashpot. The contact mechanism is actuated by the upward movement of an armature, or core, in response to the magnetic pull of the current coil. Resistance to this upward movement is effected by the oil dashpot piston mechanically connected to the armature.

The time delay, produced by the resistance of the piston to movement, can be adjusted by turning a valve disk, which opens or closes bypass holes in the botom of the piston, to vary the rate of oil flow through the piston. The trip current setting is adjusted by moving the armature stem up or down with respect to its initial position.

Magnetic overload relays have either an automatic reset contact arrangement or hand reset attachment. A series of

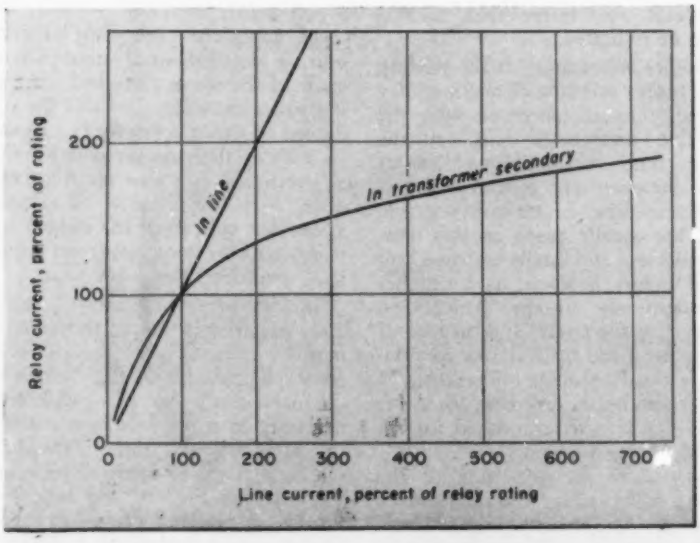


Fig. 11—A typical comparison of the relationship between relay current and the line current obtained with a saturated core transformer.

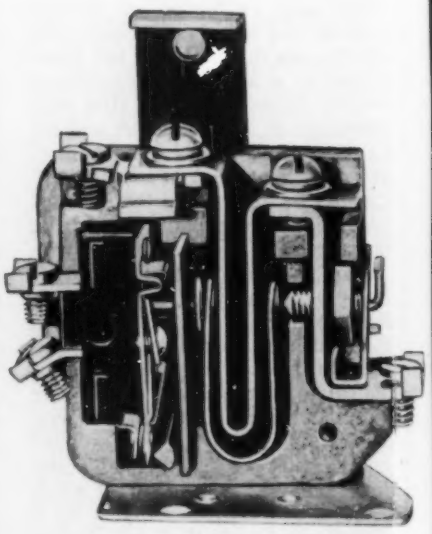


Fig. 12—Typical arrangement of component parts in a bimetallic thermal overload relay.

different coils gives an over-all continuous current range of from 1 to 700 amperes.

Principal features of the time limit overload relay are a wide range of adjustment both in tripping current and time delay settings, retention of calibration, reliability, and adaptability to either hand or automatic reset. Unlike the thermal overload relay, which reflects a proportionate rise of the motor temperature, the time limit magnetic relay is less responsive to an integration of the motor current and, therefore, is to be more generally applied with respect to a definite percentage and duration of the overload. In comparison to the characteristic curve of the thermal overload relay, the magnetic overload trip time is much shorter throughout the entire range of overload current values.

The family of curves in Fig. 13 show the adjustment in tripping time that is possible by changing the amount of opening in the dashpot piston. In an application, the motor user would adjust the opening to correspond with the maximum time he desired his motor to sustain a certain value of overload. The variation in tripping time under different conditions of ambient temperature is slightly greater when the quantity of oil flow through the piston opening is a minimum. The current at which the relay trips, however, is not affected by changes in ambient temperature, since the magnetic pull of the armature is entirely dependent upon the current.

For 50 to 55 deg C rise motors, the setting should be approximately 100 percent of the motor full-load current. Settings may be lower where the motor load current is lower than that of full load and it is desired to match this condition with the relay. Also there may be certain peak loads in excess of full load that the motor must sustain for a definite time period, but no longer, after which it is desirable to quickly disconnect the motor from the line. The current setting and the time setting of the relay can be adjusted to fulfill this condition.

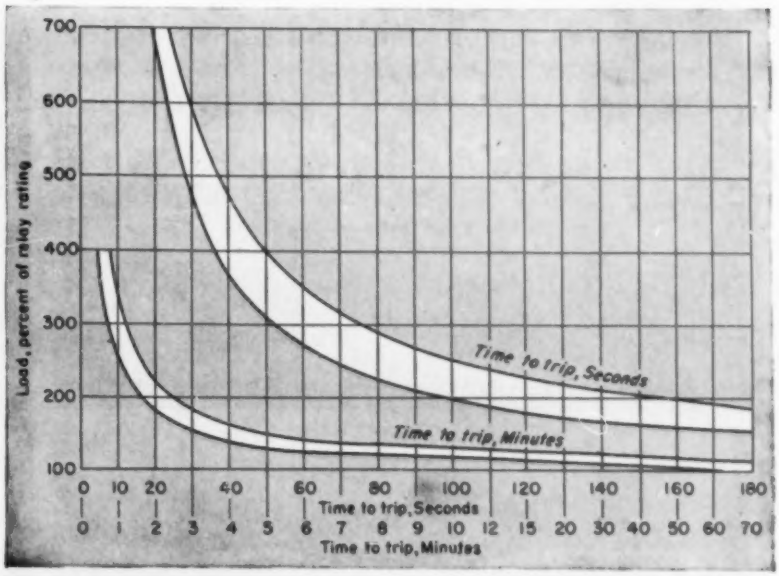

Load, percent of relay rating
700
600
500
400
300
200
100
Time to trip, Seconds
Time to trip, Minutes
0 10 20 40 60 80 100 120 140 160 180
Time to trip, Seconds
0 1 2 3 4 5 6 7 8 9 10 12 15 20 30 40 50 60 70
Time to trip, Minutes

Fig. 10—Range of trip time at various overloads for one type of thermal overload relay equipped with a long time heater unit at 40 C ambient.

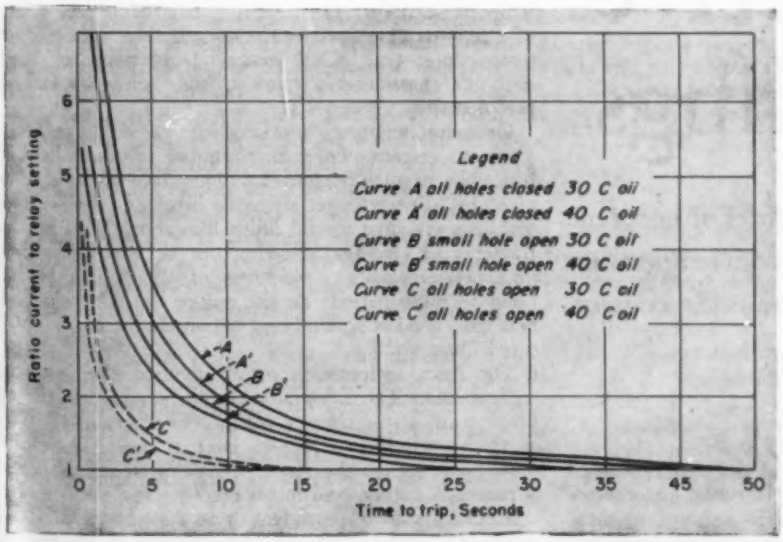
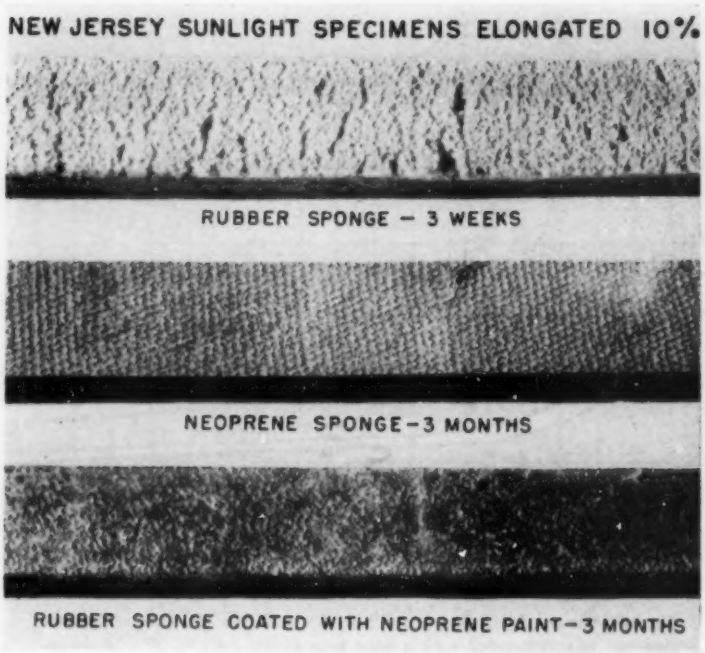


Fig. 13—Tripping times of a time limit magnetic overload relay for different amounts of piston hole openings and with the dashpot oil at two temperatures.

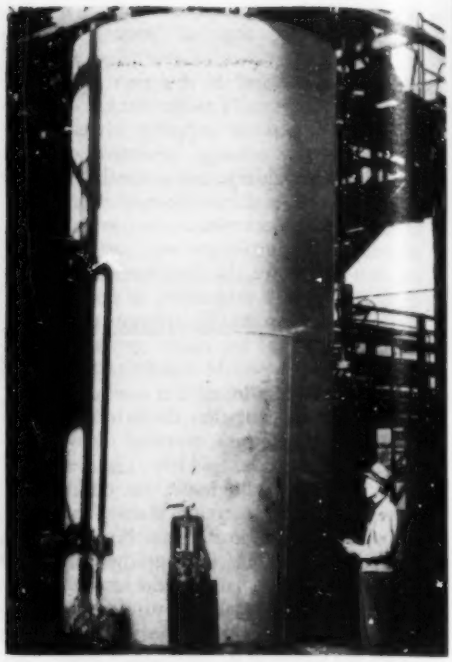
INSTANTANEOUS TRIP MAGNETIC OVERLOAD RELAY. Where the maximum running torque or current of a motor should never exceed a certain definite value, the time limit feature of the oil dashpot device is objectionable. For such applications, an instantaneous trip overload relay is desirable. This relay is essentially the same in construction as the time limit magnetic relay except that the dashpot with its retarding effect, is omitted. The current setting is adjusted by moving the armature upward or downward on the stem.

Applications of the instantaneous trip magnetic overload relay are usually confined to the field of limiting the motor torque. Quite often the relay's principal function is to protect the driven machinery from the effects of excessive stresses caused by stalled loads; for example, material handling equipment such as conveyors and baling machinery.

On certain d-c motor applications, the instantaneous trip overload relay is sometimes employed to limit the armature current to a safe commutating value. Frequently a thermal overload relay in conjunction with the instantaneous trip device is used to protect the motor from sustained overloads occurring below the current setting of the instantaneous trip relay.


NEW JERSEY SUNLIGHT SPECIMENS ELONGATED 10%
RUBBER SPONGE — 3 WEEKS
NEOPRENE SPONGE—3 MONTHS
RUBBER SPONGE COATED WITH NEOPRENE PAINT—3 MONTHS

NEOPRENE HAS EXCELLENT RESISTANCE to sunlight. Natural rubber sponge (a) elongated 10 percent and exposed to New Jersey sunlight for 3 weeks has deteriorated. Neoprene sponge (b) and neoprene coated natural rubber sponge (c) identically tested for 3 months show no deterioration.



THIS 15,000 GALLON TANK used for storage of concentrated hydrochloric acid is protected externally from spillage by neoprene paint. The coating has withstood 2 years service without effect.

Neoprene Protective Coatings

The inherent protective qualities of neoprene rubber are now available in room temperature curing solutions with high solids content.

L. S. BAKE
E. I. Du Pont de Nemours & Company

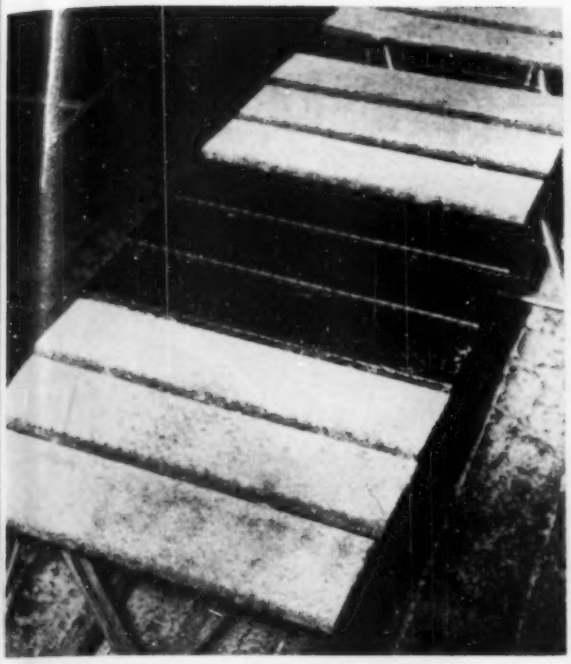
BECAUSE of its combination of physical and chemical properties, neoprene is a suitable coating material for protection against corrosion. Not only is it resistant to most chemicals, oils and sunlight, but it also has excellent resistance to thermal shock, wear and mechanical abuse. However the use of this material was formerly limited by the difficulties of applying it in sheet form. Later when the material became available in solutions that can be brushed or dipped on, the need for oven curing it at above-room temperatures was a handicap that limited its use. Recently there has been developed a neoprene solution that can be cured at room temperature, thereby making it practical and economical for many new applications.

The new neoprene solution, known as type KNR cures at room temperature in 24 to 48 hr. It has the same chemical resistance and practically the same physical properties as the conventional neoprene solution, the room temperature curing feature being effected by the addition of a recently developed accelerator. Besides curing at room temperature, type KNR neoprene solution has another desirable characteristic, namely, high solids content with low viscosity.

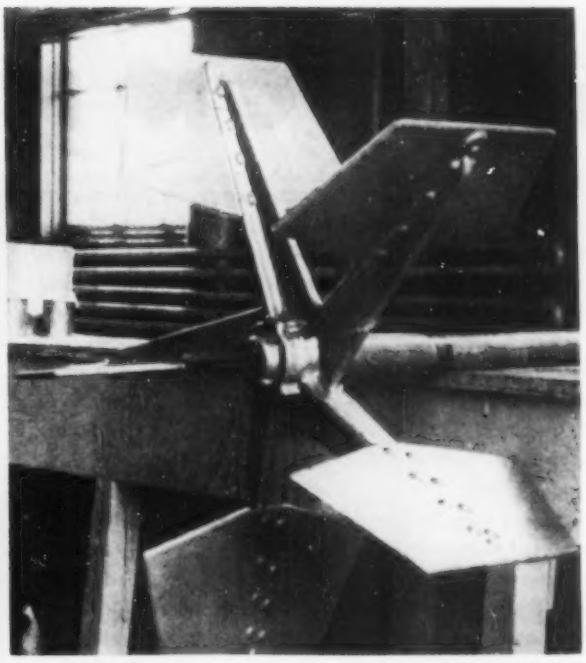
Ordinary neoprene solutions have a solids content of 35 to 40 percent. For natural rubber solutions it is even less. The new-temperature solutions have a solids content of 60 to 70 percent, yet are easily brushable. A single dip of brush will give a solid finish film about 1/64 in. thick. By repeated coatings, allowing one or two hours drying time between coats, a thickness of $\frac{1}{16}$ in. can be built. Longer drying periods do not reduce the adhesion of the next coat, good adhesion being obtained even on thoroughly cured films.

The room temperature curing solution does not come ready-mixed. The accelerator cannot be added to the neoprene paint at the time of manufacturer because it would cause the material to jell in the container. Therefore it must be added to the paint just prior to its application. It comes as a slurry and mixes readily. The pot-life of the accelerated paint is dependent upon the amount of accelerator added and the ambient temperature at the time the coating is applied. By adjusting the amount of accelerator added, the usable life of the mix may be as much as 24 hours or longer and still have the cure of the dry film proceed at a satisfactory rate.

Before the addition of the accelerator, the paint has a



ANTI-SKID APPLICATION of neoprene on steel steps. The steel is first primed with a chlorinated rubber type adhesive and a thick coat of accelerated brushing compound applied. Sand is then sprinkled on the surface and rolled down.



THIS IMPELLER was coated with neoprene brushing compound. The edges are covered with a trowelling compound that has practically the same composition. A lower solvent content is used to give higher viscosity to the trowelling compound.

can stability of a year or longer. One manufacturer of this paint has eliminated the annoyance of adding the accelerator at the time of application by adding a smaller amount of accelerator at the time of manufacturing the paint. A can stability of 6 to 8 months for the one-part paint is claimed. Of course the time required for curing the dried film is longer.

Although compositions can be made in various colors, more sacrifices in corrosion and abrasion resistance must be made because of the necessity of not using carbon black in the compounding. Carbon black is the most chemically resistant filler used and it also improves the resistance of the material to abrasion.

Accelerated neoprene paint can only be obtained in the darker shades. Light pastel colors are not practical because of the inherent tendency of neoprene to darken on aging. Some of the suitable colors are red, blue, green and brown.

For most maintenance coatings on large storage tanks or process vessels it is customary to apply one coat of chlorinated rubber adhesive primer and two coats of the accelerated neoprene paint. Where extremely corrosive conditions prevail, the neoprene coat can be built up by repeated brushing.

In coating pumps, valves, fittings and other parts to be protected from corrosion care must be taken in handling the parts. Neoprene coatings not only must be dried but must also be vulcanized before they can be subject to any appreciable amount of rough handling. The dried film is comparatively soft at first and only develops its ultimate abrasion resistance when allowed to vulcanize at room or elevated temperatures.

In spite of the softness of dried, uncured neoprene films assembly line coating would be effected by providing the proper setup. For speed of operation oven curing would be necessary. A conceivable arrangement would be to convey the parts of a sand blast operation to a primer spring and on through a drier for drying the primer. The parts would then move to the next station where the first coat of neoprene would be applied and again through a drier. The final coat or coats would be applied by repeated routing of the parts through this last station.

After the required thickness of dried coating was applied the parts would then go through a curing oven. The length of time required for cure would depend upon the temperature, which would have to be low enough to prevent blistering if there were any solvent remaining in the film.

Probably a temperature of 260 F for 30 minutes would be sufficient. A higher temperature and shorter time could be used if the film were completely dry.

Fields of Application

There are two basic fields of application of neoprene coatings—as protective finishes on functional machine parts subject to corrosion and abrasion, and as a repairable maintenance coating on large industrial equipment such as tanks, ducts and piping.

Neoprene's chemical, oil and abrasion resistance make it an effective coating material for valves, pumps, liquid meters, impellers and other hydraulic or processing equipment.

The highly alloyed ferrous metals and the high cost nonferrous metals can in many cases be replaced with a neoprene coated cast iron or carbon steel with resultant savings in critical materials and in cost of equipment.

Various factors that enhance metallic corrosion, such as velocity of liquid, differential aeration conditions, fungus growth and galvanic coupling, can be prevented by coating the metallic surface with neoprene paint. The uniformity of behavior under varying conditions will reduce failures and cut service and replacement costs.

Calculator Uses Same Gears for Addition,

This calculating machine, designed by Rupert Starret, design engineer of Johnson Machine Company, Bridgeport, Conn., uses a total of about 500 parts as compared with 1,800 parts in conventional machines of this kind. The savings in parts was accomplished mainly in the carry rack section of the machine where provisions have been made to use the same accumulator gear (10 tooth gears that register mechanical input signals) for both addition and subtraction as well as totaling operations. Previous designs use separate accumulators for each of these actions.

The key rack and the actuating mechanism follow conventional designs. Key pins limit the distance actuator racks under the keys will travel. Springs, extended by the hand lever action, power the actuator racks. The racks are in constant engagement with the actuator gears and rotate them a distance (number of teeth) according to the number on the key that stopped the actuating rack. These elements move through their prescribed distances and return to normal with each completed stroke of the hand lever.

Opposite each actuator gear is a corresponding 10 tooth accumulator gear. Each tooth represents one digit in our decimal scale, with an extra wide tooth for 0 or ten. For subtraction, a sequence cam brings the accumulator gears in mesh with the actuating gears during the forward movement of the hand lever and they turn backwards. Gears are released during return of the hand lever.

For addition, a second sequence cam holds them out of engagement with the actuator gears until the return stroke of the hand lever starts. Then, as the rotation imposed in the actuator gears is returned to normal, it is transferred to the accumulators and they register the desired number in forward rotation.

When the accumulators are not engaged with the actuator gears, they mesh with teeth on individual carry racks that carry one digit to the next gear. If an accumulator turns past its tenth tooth, the extra width alerts the release pawl for the carry rack at the accumulator gear of the next higher order. During the next engagement with its corresponding accumulator, the alerted carry rack transfers one tooth width of rotation to its gear either in a positive or negative direction, depending on which way the gear was turning that initialed the action.

WITH THE REDUCED NUMBER OF PARTS required by using same components for both adding and subtracting operations, the case for the new calculator can be made smaller and lighter than conventional machines. It uses a normal 9 digit keyboard. The model shown here is manually operated but an electric motor and drive can be included as an accessory with the mechanism to produce multiplication or division operations.

SEQUENCE OF ACTION

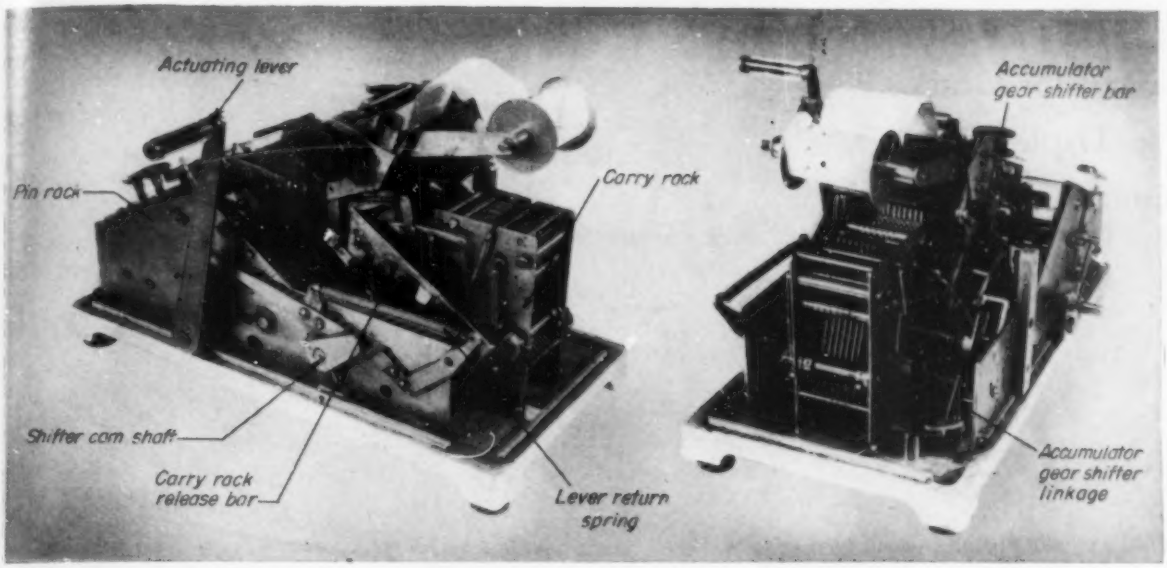
ADDITION:

During forward lever motion

1. Actuator rack turns actuator wheel to extent of travel as established by key and wheel positions print bar to correspond.
2. Carry mechanism is released. If a carry rack is alerted, it drops and rotates the accumulator wheel of next higher order one tooth.

During return lever motion

1. Ten tooth accumulator release from carry rack and engage actuator gears.
2. Carry mechanism is re-energized.
3. Racks, pulled by lever spring, return to normal and transfer rotational value to accumulator gears. Any accumulator gear rotated through its extra wide tenth tooth will alert carry pole of next higher order.
4. Accumulator gears return to carry rack.



LEFT VIEW of calculator with cover removed shows linkage between the hand lever and the accumulator gear shifter cam bar. This shaft also carries the lever that actuates the carry rack timing linkage for totaling the rotational values. Imposed in the accumulator gears, the engagement action is the same as that for subtraction. But all the carry pawls are brought in to act as lugs to stop each gear when its tenth tooth reaches a common reference line.

REAR VIEW of calculator mechanism. Accumulator gears (not exposed) are mounted in a frame that rotates with the square shifter bar. A cam follower slides along the square bar in response to shifter linkage, to be positioned over addition, subtraction or total cam as direct at keyboard. Rotation affected in each gear before it stops is transferred back through its corresponding actuator and type rack where the arithmetic rotation equivalent is printed on paper.

Subtraction and Totaling Operation

SUBTRACTION:

1. By pressing subtraction key, carry is released and if a carry pole has been alerted from previous adding operation its gear will be rotated one tooth. Timing cam follower is moved to subtraction cam.

Pull stroke of hand lever

1. Accumulator gear moves from carry racks to actuator gears.
2. Actuator gears rotate accumulator gears. If a gear passes through its tenth tooth, the carry pole of the next higher order is released, and falls a distance of one tooth. *Notice that it is not engaged with its gear.*

Return stroke of hand lever

1. Accumulator gear leaves actuators and returns to carry racks.
2. All carry poles are re-energized. Carry poles released in step 2 above are moved back to join the others and in so doing turn their engage gears one tooth further in the subtract direction.
3. Timing cam follower returns to adding cam.

TOTALING OPERATION:

By pressing totaling key, carry mechanism is released and any alerted carry pole transfers one tooth rotation to its gear. Carry pawl holding bar is rotated to firmly position pawls in path of tenth tooth in accumulator gears. They act as clearing stops. Timing cam follower is repositioned over totaling cam (same shape as subtraction cam).

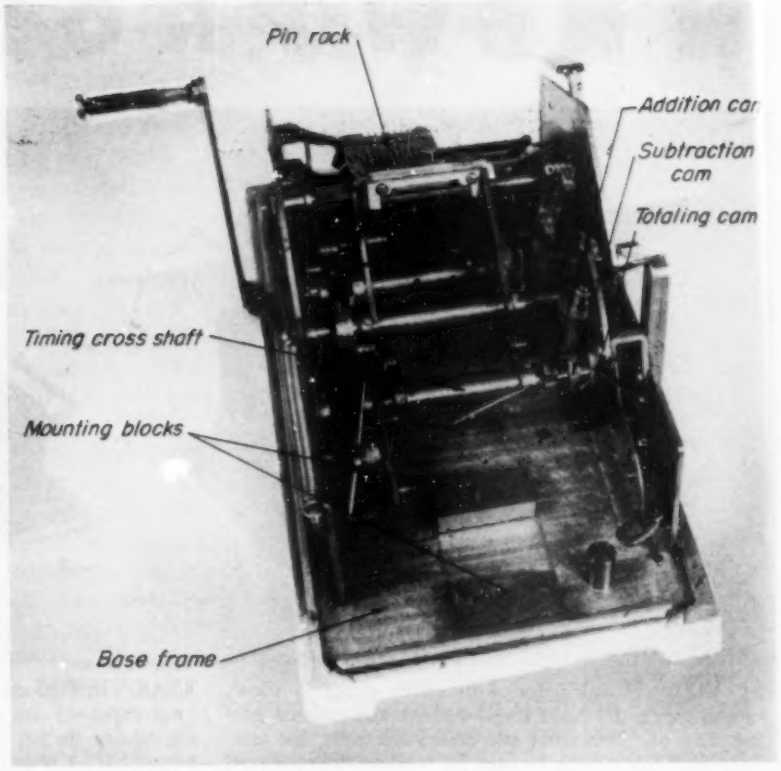
Pull stroke of hand lever

1. Accumulator gears move from carry rack to actuator gear.
2. Each actuator gear rotates its accumulator until local movement is stopped by action of tenth tooth on carry pawl. Additional movement of hand lever is taken up by spring on actuator rack. Meantime the various print bars have been positioned according to where the actuator gears were stopped and when the lever reaches full rear positions, they are tripped and print numerical value of accumulated rotation on the paper.

Return stroke

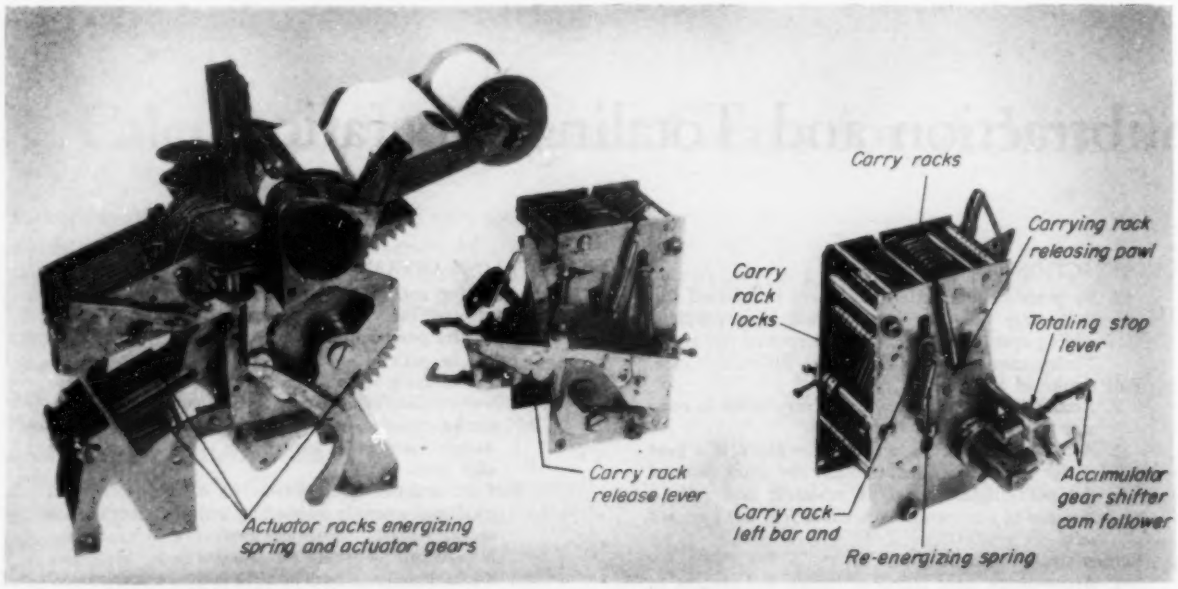
All elements return to normal rest position.

Calculator Gears Do Triple Duty (continued)



FOR EASY SERVICING, the machine can be disassembled into three sections held together by screws; the base frame and pin rack, the actuating mechanism and the carry rack section. Separations take place where motion is transferred through cam shafts or springs that can be easily disconnected.

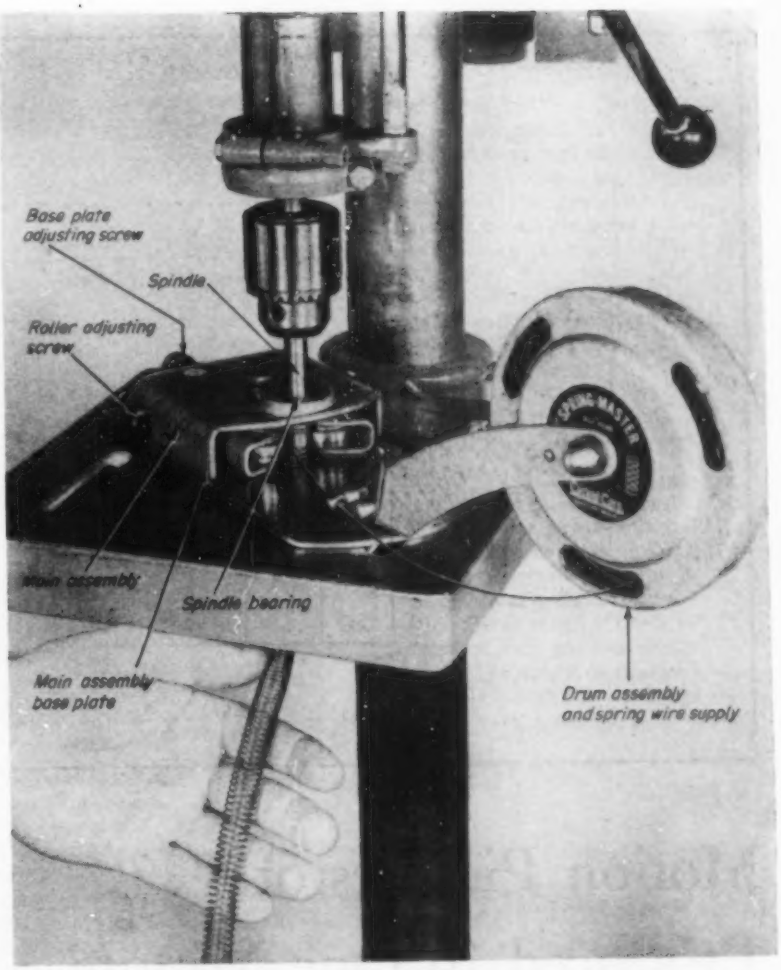
OPERATION CAMS fit on the timing cross shaft mounted on the base frame. Screws that hold sections together fit into mounting blocks.



ACTUATING MECHANISM and carry rack separated but in proper relative position as seen from left side. When carry rack release lever is permitted to fall, carry rack lifts bar, falls with it. All those carry racks alerted by wide tenth tooth on accumulator gears have been released from secondary linkage and follow lift bar down. The distance travelled equals rotation of one tooth on accumulator gear.

ON RIGHT SIDE OF CARRY RACK is the shifter cam follower that is moved along square shifter bar to be positioned over one of the sequence timing cams. The lift bar raised by action of the carry rack release lever energizes all the carry racks. When a carry action is required, only those racks released by release pawl will fall when the left bar drops.

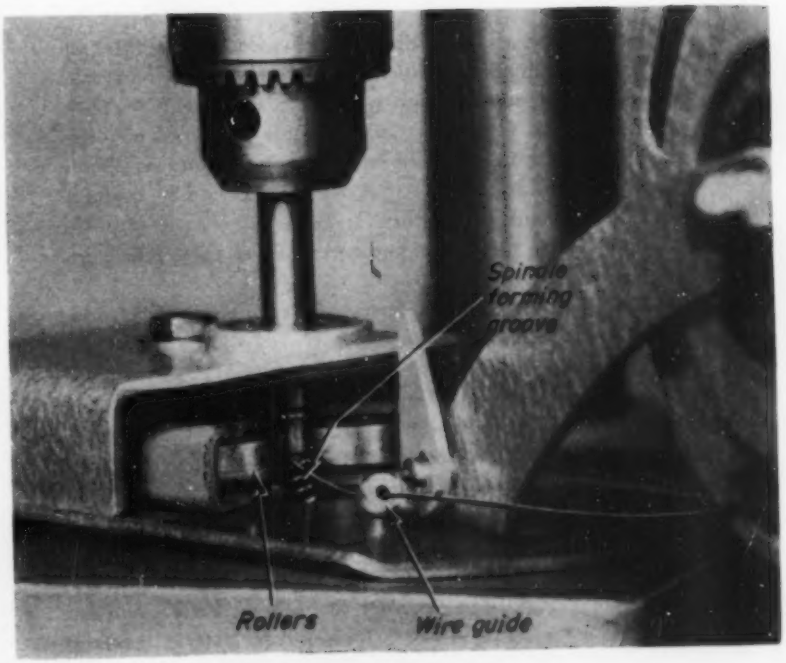
SPRING-MASTER drill press attachment consists of a drum assembly that carries the spring wire supply, a main assembly where the spring is formed, and a set of grooved spindles to control the spring internal diameter. A bolt and thumb nut fasten main assembly and drum assembly to drill press table. Adjustment screw in rear of main assembly adjusts position of housing on base plate to vary position of spindle bearing relative to rollers. Also the rollers can be adjusted for close or wide spacing to fit wire size. Finished coil spring moves down through opening in main assembly base plate and drill press table.



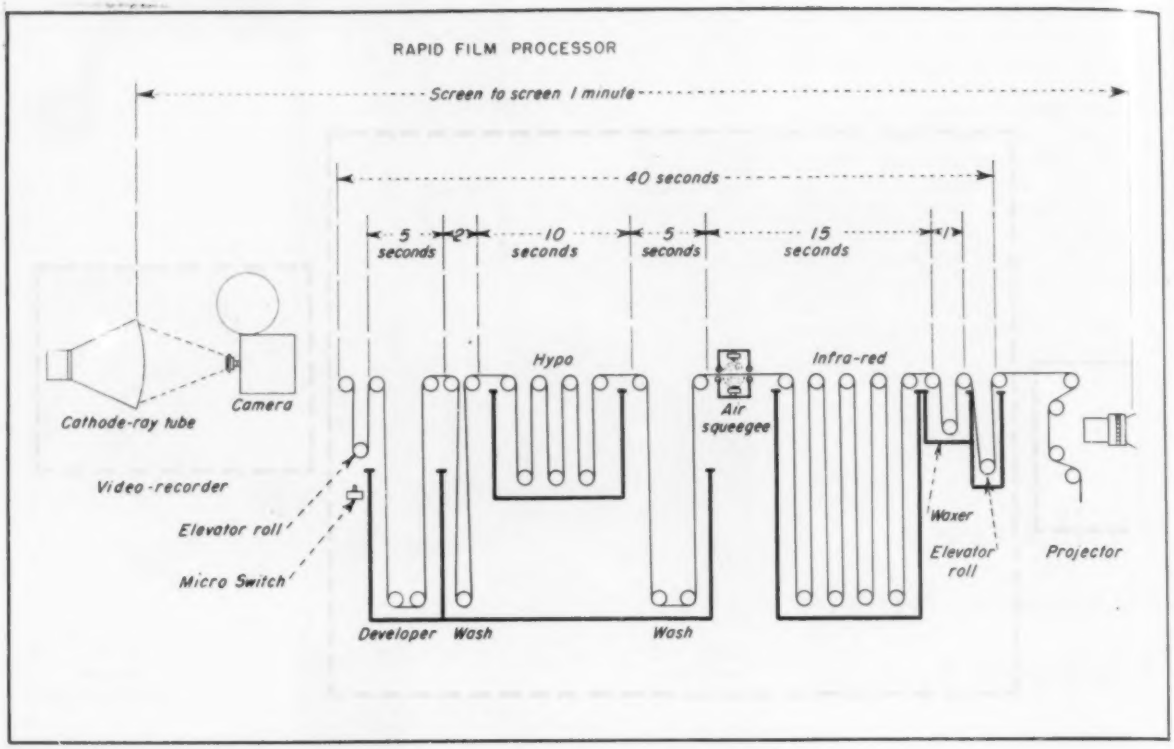
Drill Press Accessory Makes Uniform Springs

A simple attachment called the "spring-master" adapts any standard drill press for the manufacture of coil springs. Made by the DoALL Company of Des Plaines, Illinois, the device can produce either compression or extension springs.

Springs are formed on spindles that carry four knurled grooves, each of a different diameter. Three spindles are available providing 12 inside diameter sizes ranging from $\frac{1}{8}$ in. to 15/32 in. in steps of 1/32 inch. Outside diameter depends on size of wire used; spring length is limited only by the length of wire used.



MAIN ASSEMBLY is a guiding device in which straight spring wire is converted to coil form around the spindle. Drill press chuck is lowered until desired spindle groove is between rollers. Pitch of the spring is controlled by level of groove with respect to roller level. Roller pressure against the wire causes the wire to be gripped and formed in the spindle groove. Rotation of spindle pulls wire from the drum assembly.



Motion Pictures of TV Produced in One Minute

Dotted boxes in the schematic diagram above outline the three independently functioning sections of the new theater television system made by General Precision Laboratory, Inc., Pleasantville, New York. When connected with film speeds matched, the combined elements can automatically record a television broadcast with sound on 16 mm film, process the film and deliver it ready for showing to commercial type motion picture projectors. It takes one minute for the signal at the television receiver to be processed and projected to the screen of a motion picture theater.

Each of the three sections will operate independently. The video recorder contains a receiver-monitor synchronized with a special motion picture camera. Here, the TV signals that pass over the cathode-ray tube at an equivalent frame rate of 30 frames per sec are converted to the 24 frame per second rate standard in the motion picture industry. This is done by electronically blanking out the picture tube until the film is correctly positioned in the camera—done at the 24 frames rate. The tube is turned off again before the next frame is pulled down. Thus no mechanical shutter is needed. When the film stops a vacuum is used to hold it flat against a fixed plate to insure correct focal adjustment. The recorder has a light-proof feed and takeup reel that are used if film is to be stored for later processing.

RAPID FILM PROCESSOR with front doors open and panels removed to show arrangement of processing compartments. Valve knobs in top panel control the temperature and pressure of chemicals as indicated by the corresponding gages. Film passes through the washing compartment twice—between developer and fixer and again between fixer and the air squeegee where air jets blow excess water off film. Each compartment is lined with stainless steel to prevent corrosion. The shiny metal concentrates the heat from this infra-red lamp on film as it passes through the dryer station.

PROJECTOR AND CAMERA use the same type of film intermittant framing mechanism and sound track drive. Here is shown the path of the film as it passes through the projector. Notice the two loops the film take (one on each side of the sound pick-up station). These compensate for changes in film length as it passes from the intermittant film drive sprocket to the constant speed wheel of the sound station.

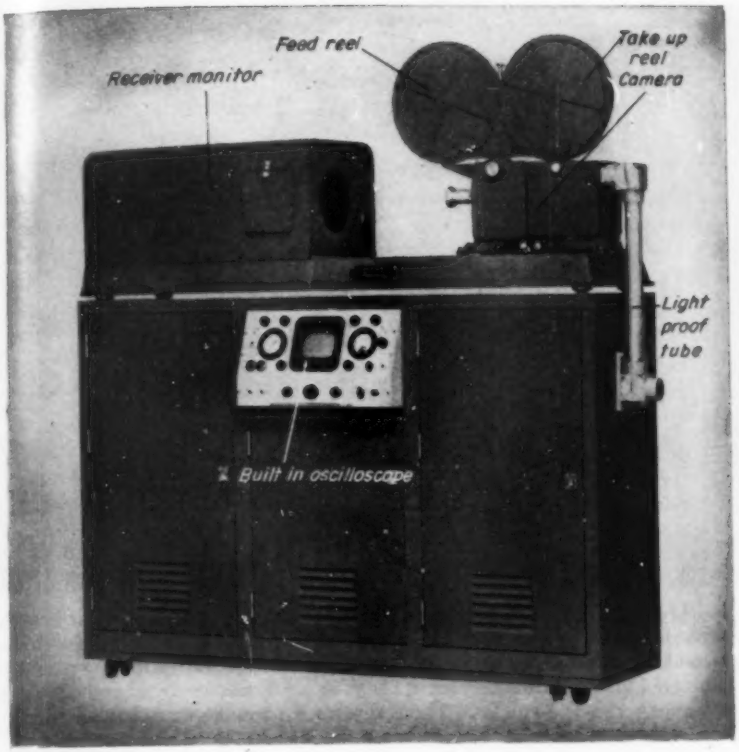
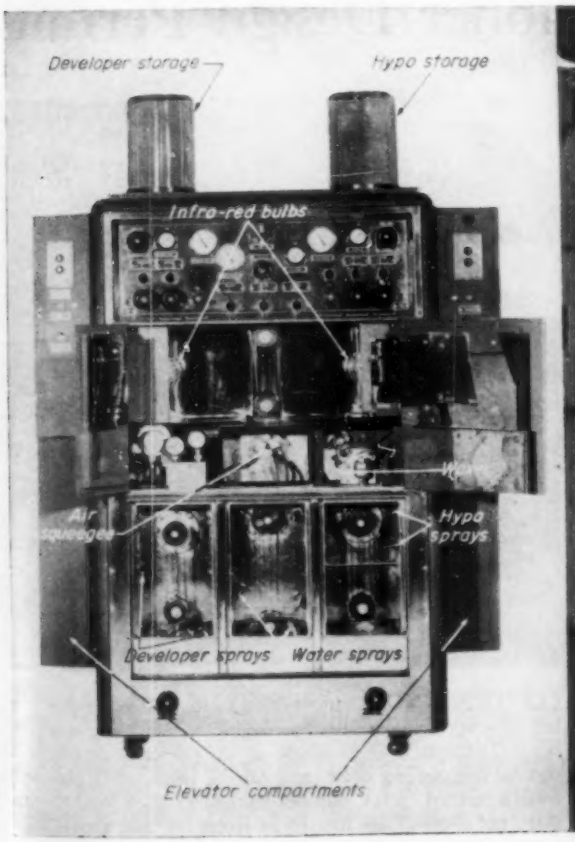
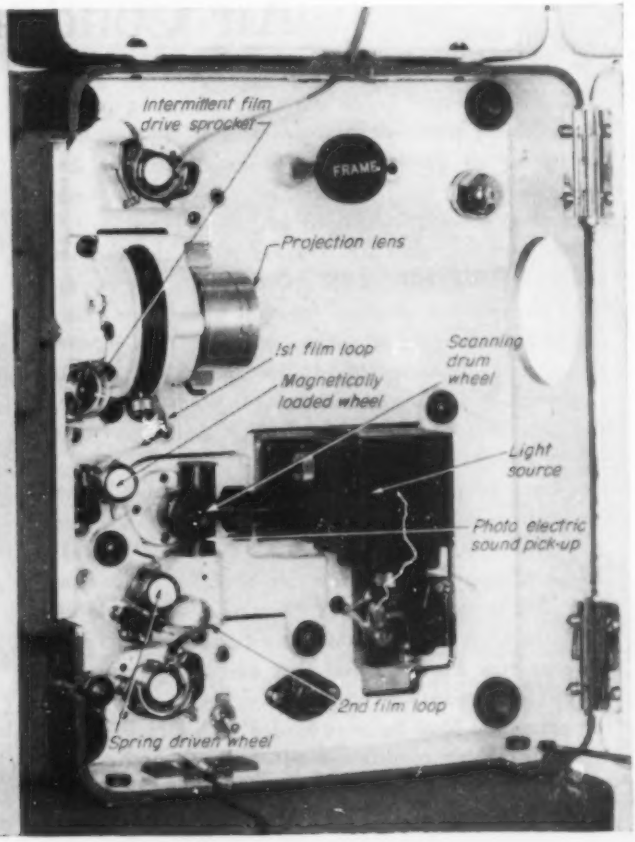
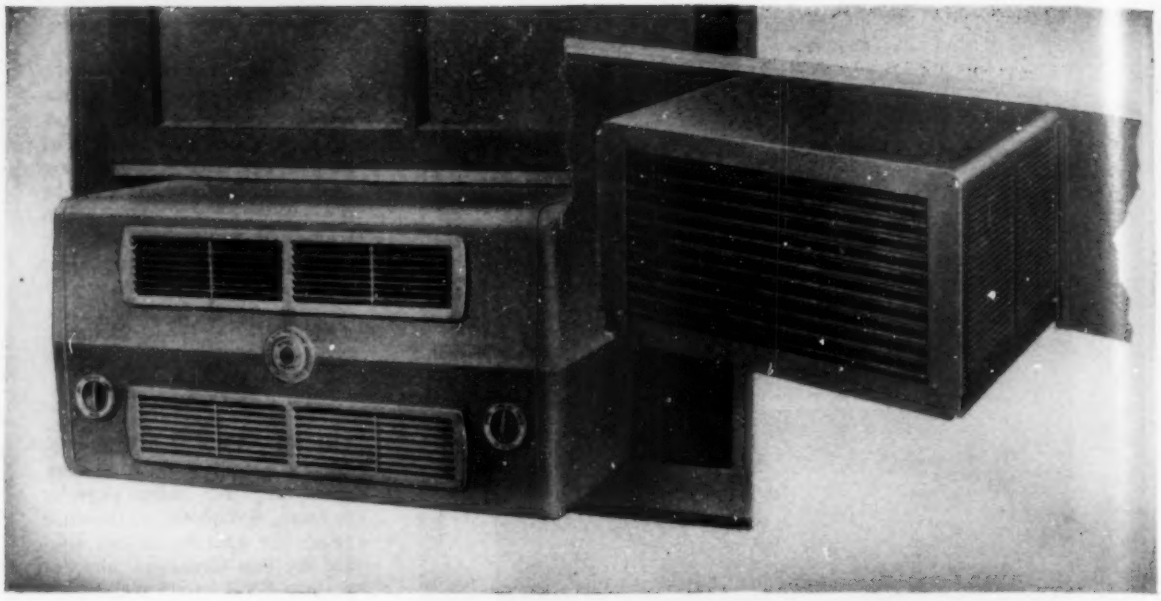


DIAGRAM SHOWS path of 16 mm film as it passes from video-recorder through rapid film processor to the projector. The camera and the processor are connected by a light-proof tube through which the exposed film passes. Both film washes take place in the same compartment as shown and film recourses over the same wheels for both. Time it takes for a frame to travel through each process is shown between the dimension lines.

TELEVISION RECEIVER synchronized with a special camera constitutes the video recorder section. A built-in oscilloscope assists the operator in establishing the best signal for film exposure. Focal length is fixed between the two sections at the factory. The camera is equipped with light-proof film feed and take-up boxes to store film.







AIR CONDITIONER PRESENTS attractive appearance on inside of room. Cabinet is made of enameled sheet steel while grilles are plastic to prevent moisture condensation. Room air is drawn in through lower grille, clean cool air is discharged out of upper grille. Exterior view shows condensor through which outdoor air is drawn. Rear housing assembly is also made of enameled sheet steel. Small unit operates on 115 v and circulates 220 cfm. ¾ hp unit is available for 115 v or 230 v operation and circulates 310 cfm. Three wire cord permits grounding.

Air Conditioner Design Permits

Recessed control knobs permit the hinging of the front cabinet of this air conditioning unit so that it may be swung up for easy access to filters with no disassembly. And a variety of acoustic materials have been applied to make it operate as quietly as possible.

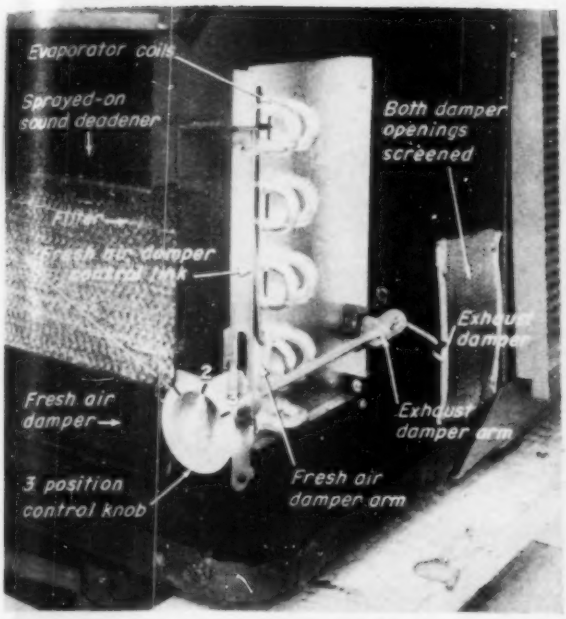
Designed for home and business offices, the unit has a welded hemetically sealed motor-compressor assembly that uses low-pressure freon-12 refrigerant. This assembly is mounted on springs and rubber to prevent noise from vibrations. In addition, panels that might sing or drum are treated with a mastic sound deadener, and heat insulating material is used in such a way that it also absorbs noises.

A single motor drives the condensor fan (that draws in outside air) and the evaporator fan (that pushes air through the cooling coils and the discharge grilles).

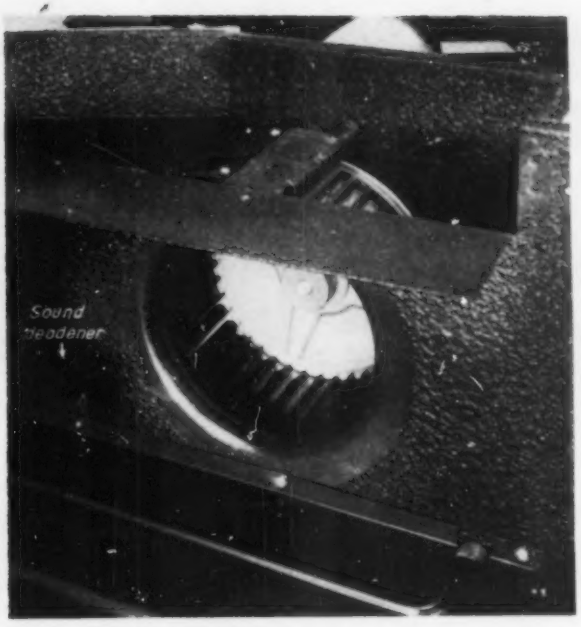
The former is an overlapping blade, pressure-type propellor design and has a slinger ring to get rid of moisture taken from the conditioned air. The latter is a pressure type blower wheel that overcomes static resistance and maintains proper air delivery even when the aluminum filter becomes loaded with dirt.

This room air conditioner called the Quiet Kool is built by the Quiet Heet Mfg. Corp. of Newark, N. J. and is currently available in two sizes: ½ and ¾ hp.

CONTROL KNOBS are recessed so that hinged front cabinet lifts up to make filters accessible without any disassembly. Thermostat is available as an optional accessory to control the cooling cycle, and can be installed in the field. Switch control (left), damper control (right), and thermostat (not shown) are located in front for easy access.

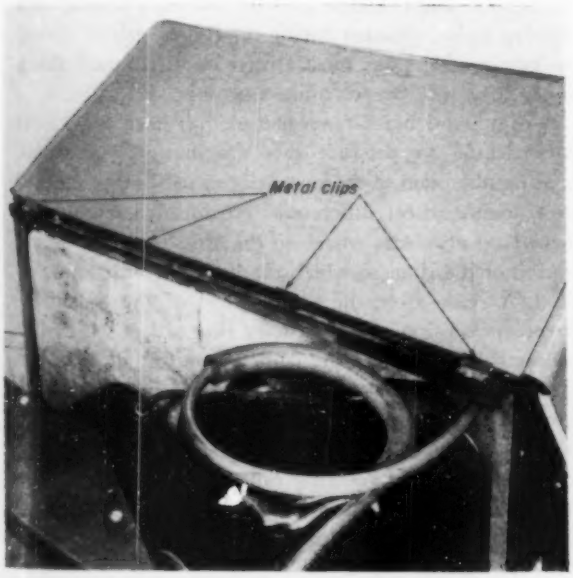


DETAILS OF DAMPER MECHANISM. Control knob has three positions: 1st position, both fresh air and exhaust dampers are closed; 2nd position, fresh air damper is open and exhaust damper is partially open; 3rd position, fresh air damper is closed and exhaust damper is wide open.

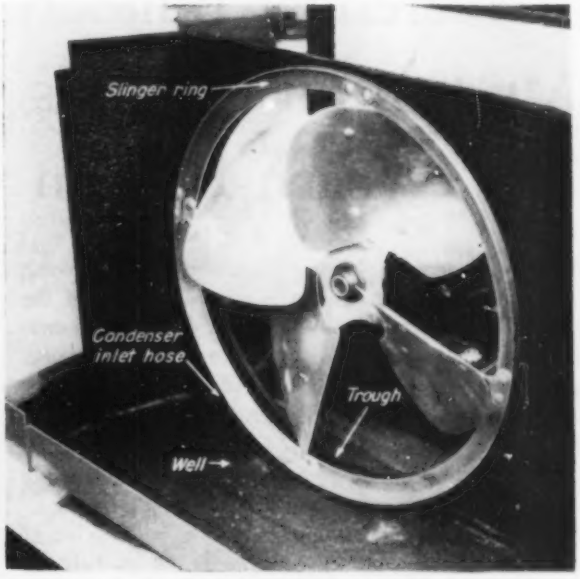


ACOUSTIC MATERIALS are used to reduce noise of unit. In this view the panels containing the pressure type blower wheel are coated with a mastic material that prevents singing and drumming. Blower forces air through cooling coils and aluminum mesh filter.

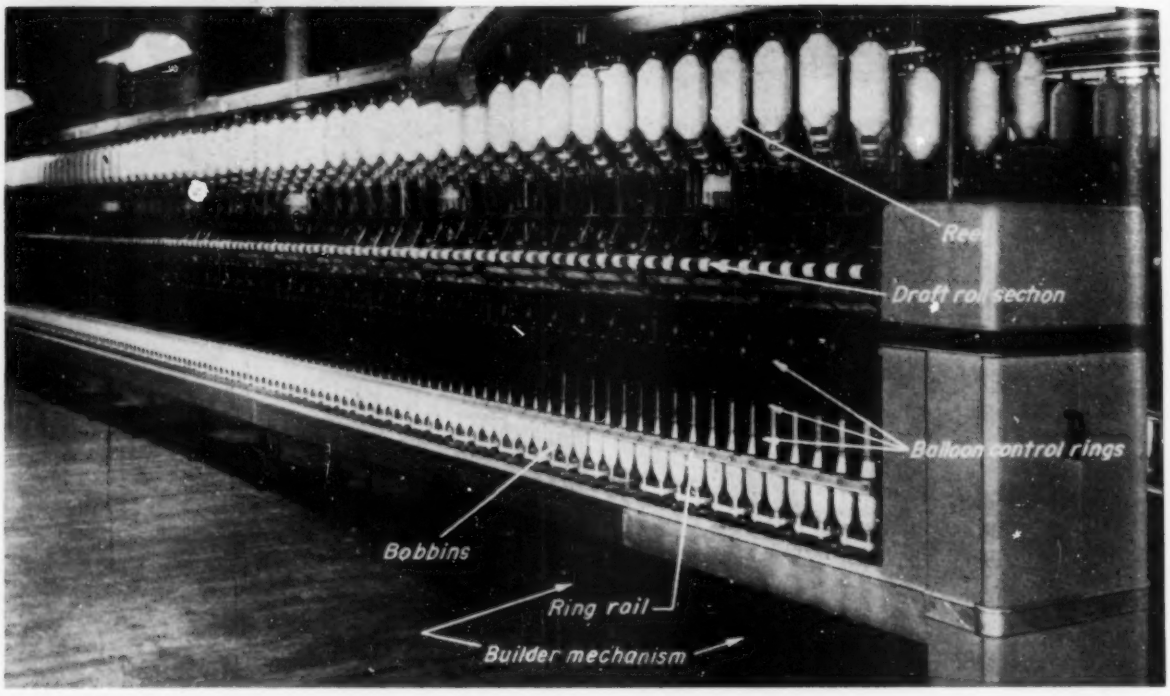
Easy Access and Quiet Operation



FRONT CABINET HINGE MECHANISM consists of simple prongs attached to the chassis. These engage into slots in the cabinet. Metal clips lock cabinet in place and permit swinging operation. In foreground is hermetically sealed motor compressor assembly. Compressor is two cylinder unit driven by capacitor start motor.



WATER SLINGER RING is combined with condenser fan. As air is drawn from outdoors, moisture forms on fan blades and is thrown against the condenser by the slinger ring. Hose from evaporator section conducts water to well in condenser section. Trough leads overflow water back into well. Panels are acoustic treated.



PRODUCTION of big packages of spun yarn on bobbins set at 4 in. centers has been made possible in this spinning frame by controlling the ballooning action of the yarn with anti-node rings as it travels from the draft rolls to the bobbins. By designing the builder mechanism to act along the longitudinal axis, the width of the machine has been held down to 27½ in. overall. It is the first textile spinning frame to use sealed bearings throughout.

Differential Builder Mechanism Controls Yarn Balloon

One of the main problems of textile mills in producing large packages of spun yarn is the ballooning of the yarn as it is delivered from the draft rolls and spun onto the bobbins. The larger package, up to almost one pound, is desirable because it reduces winding costs and knots and lengthens the doffing cycle. Engineers of Saco-Lowell shops, Biddeford, Maine, solved this problem with their new Gwaltney spinning frame that can produce the big package sizes while using conventional spindle speeds.

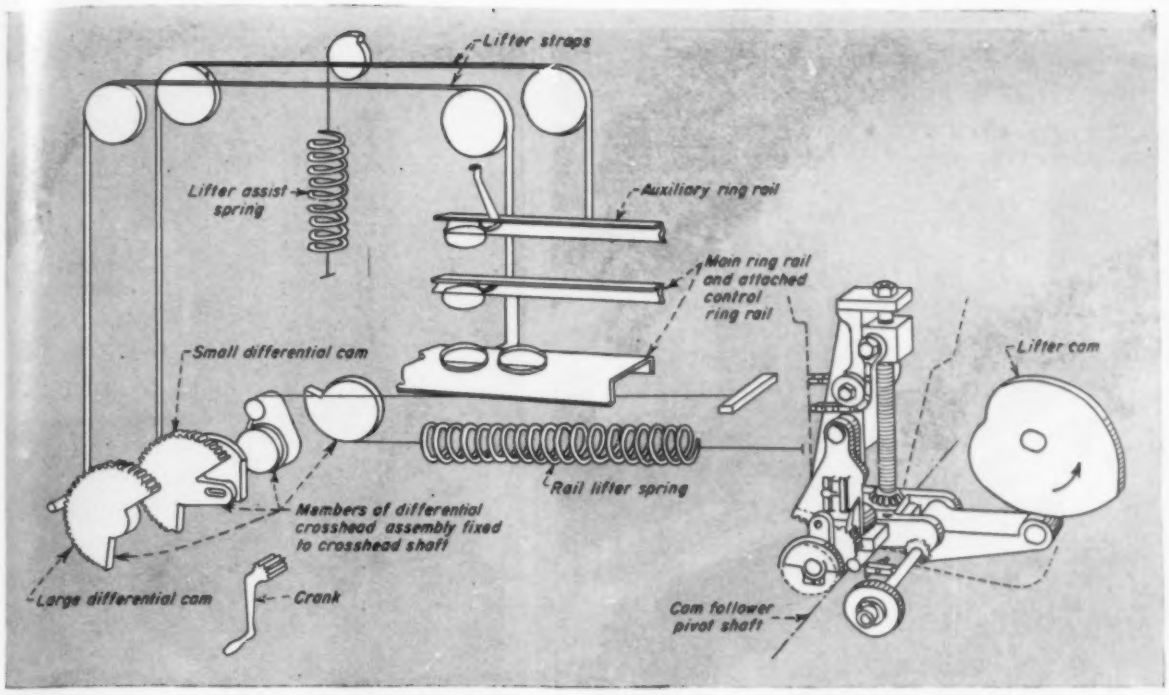
The answer to the ballooning problem was the use of two anti-node rings that restrict the size of the balloon. Located between the threadguide and the bobbin, the rings move in accordance with the traverse of the ring rail.

As the distance between the ring rail (the rail that moves up and down to distribute the new yarn evenly over the bobbin) and the draft rolls is constantly changing, as directed by the builder mechanism, the length of the balloon also changes. To keep the yarn tension and twisting action constant during the full length of travel, the two control rings must always be distributed along the balloon in a predetermined manner.

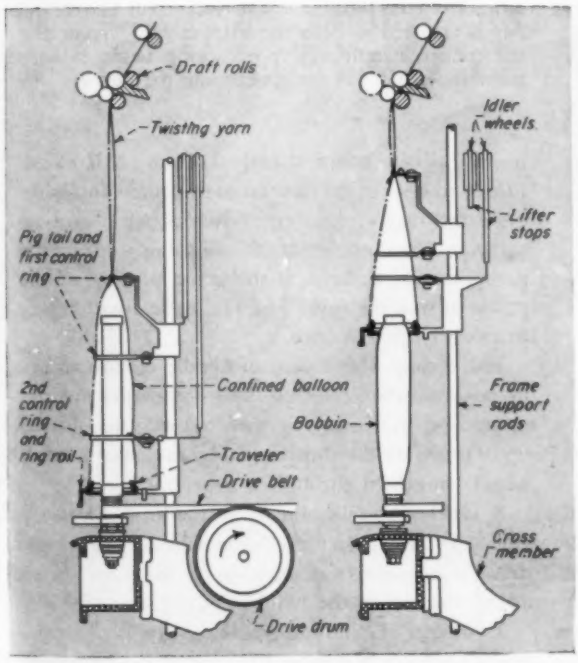
A compound builder mechanism has been built into the machine to produce this distribution. A single rotating plate cam in the base delivers oscillating motion to a double wheel differential crosshead assembly. A chain from the large wheel on the crosshead directs the motion of the ring, to which the bottom control ring is fixed. A chain from the small wheel of the crosshead directs the motion of an auxiliary ring rail to which the middle balloon control ring and a pigtail guide loop are fixed. The diameter ratio of large to small wheel is about 2 to 1. This produces one-half the movement in the top rail as is produced in the ring rail.

Actual weight of the ring rails is not carried by the builder motion but is supported on two heavy springs in the linkage. The builder motion directs the action of these springs.

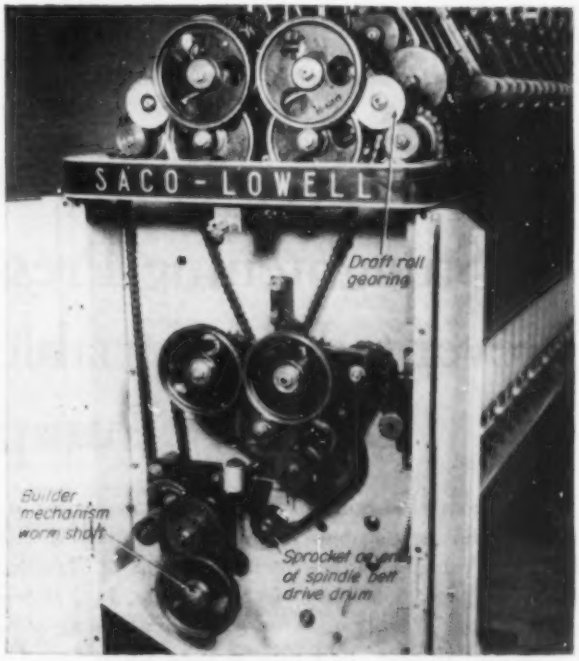
The shape of the main cam determines the speed the ring rail moves at any given position. By increasing the speed of the rail towards the end of each stroke the tapered points on the bobbins are produced. Cam shape determines distribution of yarn over the bobbin.



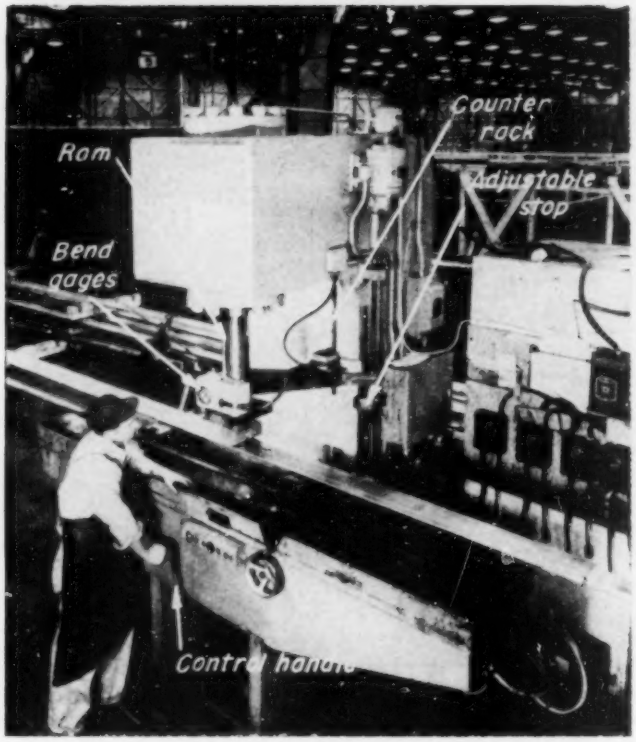
BUILDER MECHANISM: Differential cams in cross-head assembly transmit builder motions of different values to ring rails. Arrows indicate direction of action as rails rise. Notice that the springs are doing the work of lifting the weight with movement being controlled by the lifter cam. Positive cam action does bring the rails down re-extending the springs but the weight of the rails is with it. Cam-shape determines the distribution of yarn over the bobbins.



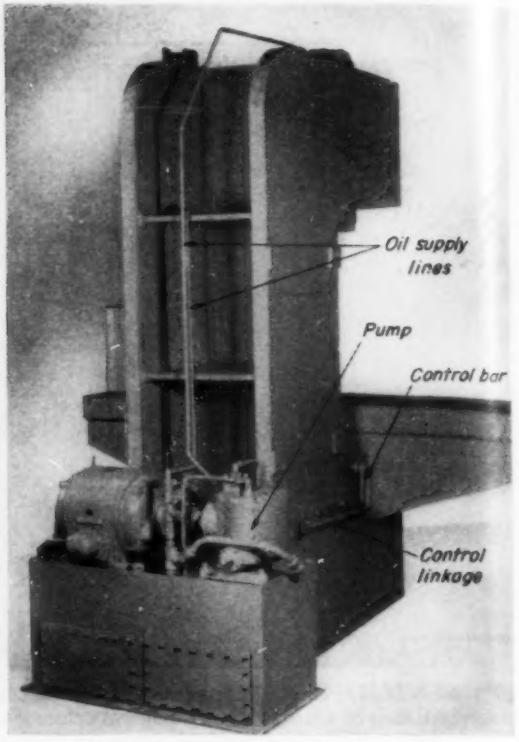
HOW BALLOONING ACTION is confined close to spindle. Pigtail guide loop and first control ring are mounted to thread board. Second control ring moves with ring rail. Notice the difference in distance between the two rails over full travel of bobbin. The traveler is a small metal loop that rides free on the main ring rail.



POWER IS DIRECTED to the draft roll gears and the builder cam worm shaft by a continuous chain drive driven by a sprocket wheel on the end of the spindle belt drive drum in the base of the machine. All the gears are cut with the same pitch and have the same size mounting shaft holes. They can be interchanged to reverse operating speeds.



RAM of this hydraulic straightening press, shown contacting a structural part of an airplane, responds directly with action of the central handle in the operators hand. When he presses down, the ram comes down; when he releases the handle the ram retracts. Gages are provided to indicate the pressure being applied by the ram or to indicate its exact position with respect to an adjustable reference. Ram stops automatically.



VARIABLE DELIVERY PUMP directs oil to either the top or the bottom of the piston depending on position of control linkage. Power to drive the pump comes from the 10 hp motor at 1,200 rpm. The control bar is attached to both the shipper bar linkage and the control handle. Shipper spring tends to keep the shipper rod down, thus keeping the ram up.

Over Travel of Straightening Press Prevented by Variable Delivery Pump

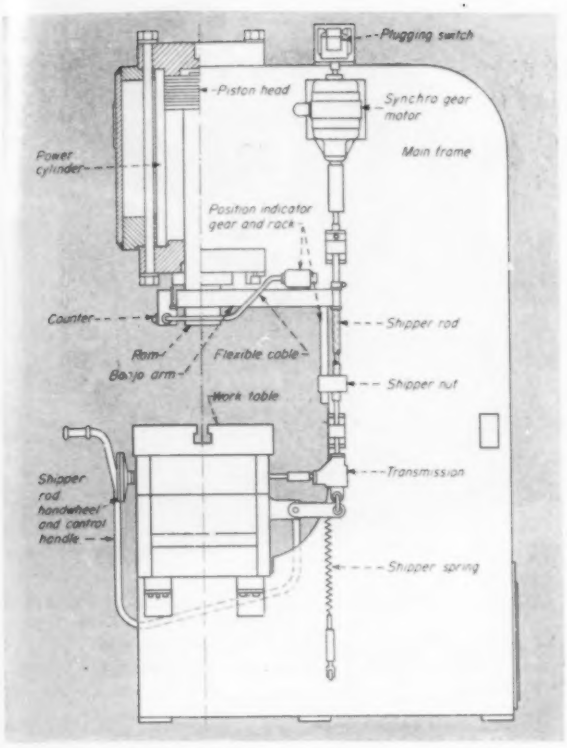
Positive control of both the up and down movement of the piston in this new hydraulic straightening press is accomplished by using a variable delivery pump to furnish the power. Designed by Hufford Machine Works, Inc., El Segundo, Calif., the press is used for straightening long sections of structural airplane parts such as wing spars.

To prevent over-bending of the work, the machine has an automatic shut off linkage between the hydraulic ram and the pump that keeps the ram from being advanced beyond a predetermined position. When an extension of the piston contacts the adjustable nut on the pump control linkage, it shifts the porting of the pump to stop the ram or, if so adjusted, to reverse the flow from the pump and withdraw the ram altogether. When a banjo arm attached to the ram contacts the adjustable nut on the pump control linkage, it shifts the porting of the pump to stop the ram. The ram action will repeat to a very close tolerance.

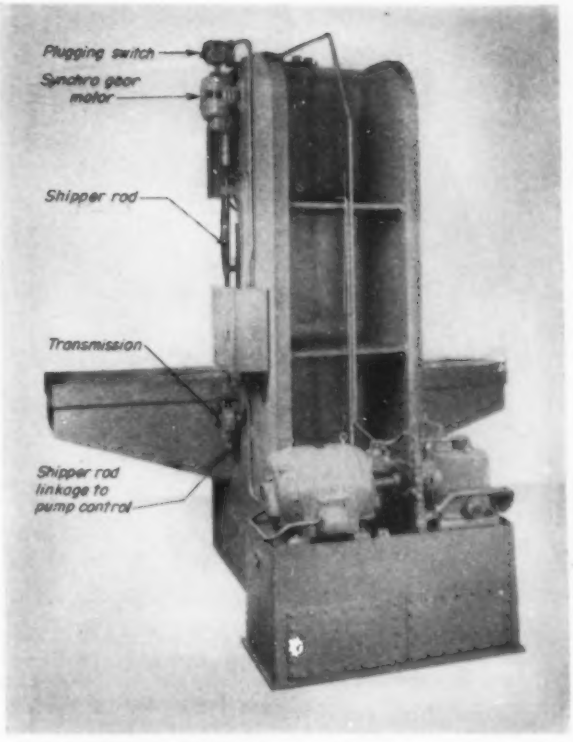
The spring loaded control handle returns to the up position when released. This withdraws the ram to starting position. The stop nut may be shifted up or down on the shipper rod by means of a hand wheel connected through a gear box.

A synchro gear motor is available as accessory equipment to replace the hand wheel. The motor drives a long screw shaft through the stop nut to adjust the nut to the height desired.

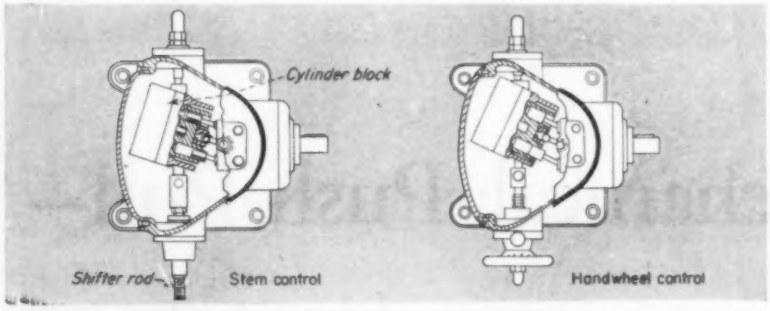
Two types of bend indicators are provided on the press. One is a dial gage attached to the hydraulic circuit and indicates actual bending force applied in tonnages from 0 to 150 tons. When bending is so light that tonnage is not readable, an automatic counter is used. This counter is gear driven from a rack fixed to the press frame.



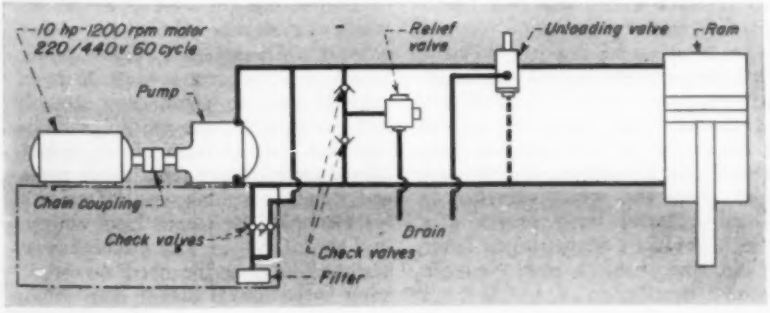
DOTTED LINES SHOW how the control handle is attached to the control bar. At left end of press (invisible in this view) is the linkage that directs action to reduce pump delivery and ultimately reverse it. When the ram lowers enough that its attached banjo arm contacts the shipper nut, further movement will shift the shipper rod down. Control bar will rotate and change pump output.



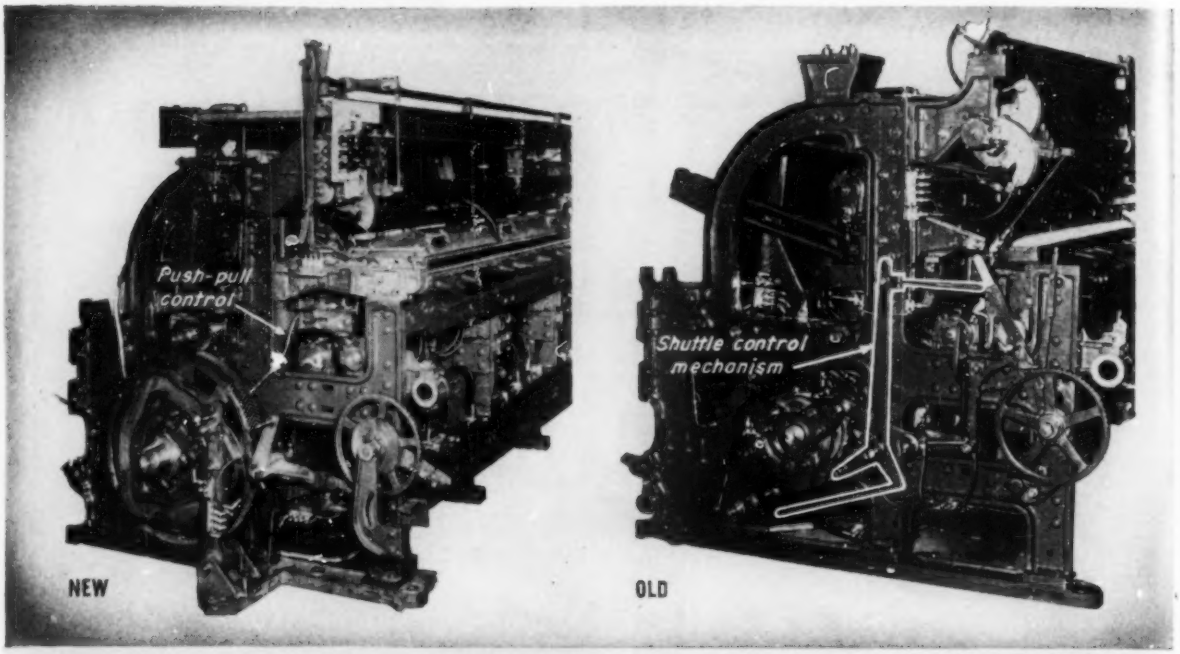
ADJUSTMENT of the shipper rod nut is accomplished by rotating the shipper screw in it and permitting it to be raised or lowered. The screws is manually rotated by a handwheel (synchro gear motor shown here is available as accessory equipment) connected through a gear box. The handwheel is graduated so that one complete revolution is equal to 0.125 in. of ram travel.



CROSS-SECTIONAL DIAGRAM of Vicker variable delivery pump used in the straightening press shows how the displacement is changed according to shipper rod position. With atmospheric intake pressure the pump will deliver 19.5 gpm at 1,500 psi pressure.



SCHEMATIC DIAGRAM of hydraulic system. Check valves from both delivery lines are parted into a single relief valve. The unloading is connected primarily with down stroke of the ram because excessive pressure is most dangerous in this position.



Crompton & Knowles Loom Works

Fig. 1—New carpet loom uses a push-pull control to operate the shuttle at higher speeds than were possible with the heavy lever system previously used. Old loom shows the many parts that were eliminated plus the improvement in appearance made possible by the pre-fabricated one piece unit.

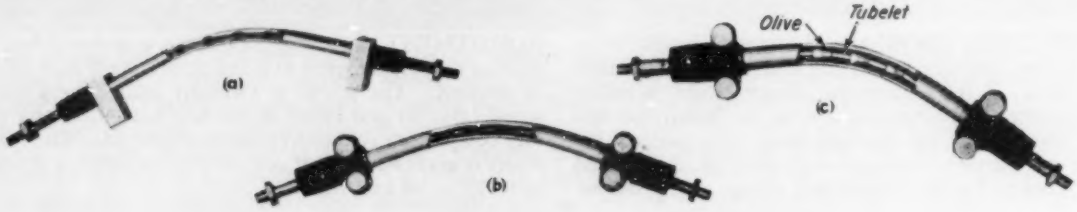


Fig. 3—This type of control is now available for three types of service: (a) for light duty; (b) for standard; and (c) for heavy duty. Refer to Table II on pg 153 for design data for each of the three different sizes.

The Mechanical Push-Pull—

HOWARD HOLMES

Vice-President, Development
Simmonds Aerocessories, Inc.

THE MECHANICAL PUSH-PULL CONTROL, in its current stage of development, offers a precise method of transmitting motion from one point to another, over long periods of time, with negligible loss of efficiency and with a minimum of maintenance.

Unlike the light, inexpensive "choke wire" familiar in numerous automotive installations, these controls can actuate sizable loads in compression, as well as in tension. Another useful feature is that the unit can be routed easily around obstructions that normally make other mechanical control devices complicated, heavy, and costly. When properly engineered into original equipment a push-pull often outlives the component it operates. Under certain conditions, it can replace rod-and-bell crank systems, pulleys and cables, chain and sprocket devices or hydraulic control lines, providing a better product appearance, fewer trouble spots, and a more versatile control system.

Contrary to the commonly accepted belief that aircraft components price themselves out of most other fields, push-pulls are now solving several industrial and automotive control problems with subsequent savings in time, material and, in some cases, initial cost. In general, however, comparisons should include all factors, such as improved performance, eliminated parts and reduced assembly time. Consider, for example, the carpet loom shown in Fig. 1. When this machine was designed to meet the need for operating speeds much higher than those

Table I — Performance Requirements

Test	Room Temp.	70±1C (158±2F)	−55±1C (−67±2F)
Backlash, in., max.	0.020	0.020	0.020
Operating Force, lb. max.	2.6	2.3	15
Max. friction lb., 5 lb. tension and compression load	6.1	5.4	25
Max. friction lb., 5 lb. tension and compression load	27	24	40
Break Away Force, lb., max.	2.6	2.3	20

Table II — Typical Design Data

	Light Duty #4L Control	Standard #5 Control	Standard #7 Control
OD of rigid tubing, in.	¼	5/16	7/16
Max. compression load* (heaviet in tension), lb.	20	40	60
Length of stroke (or travel)	From 0 to 5 in. with standard fittings; longer on special applications.		
Weight with rigid tubing lb/ft.	0.1	0.12 (average)	0.20 (average)

*See text below

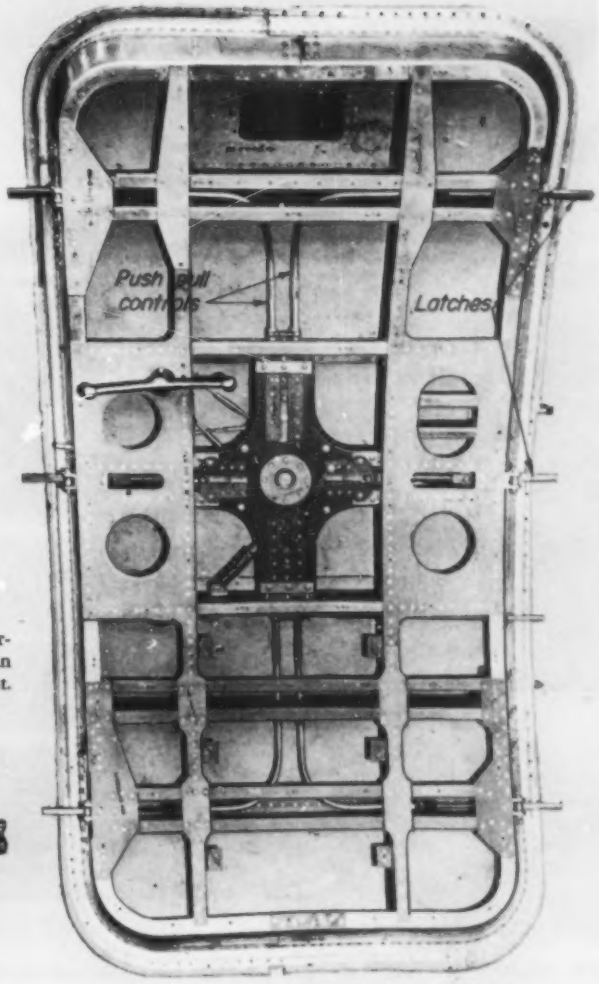


Fig. 2—Door from Martin 404 uses push-pulls to operate the latches. Loads are normally 50-60 lbs but can exceed 400 lb if considerable mis-match is present.

Fig. 4—Made by Teleflex, this linkage consists of a wire wound in a helix about a solid cable core.

Simmonds Aerocessories, Inc.

A Remote Control for Industrial Use

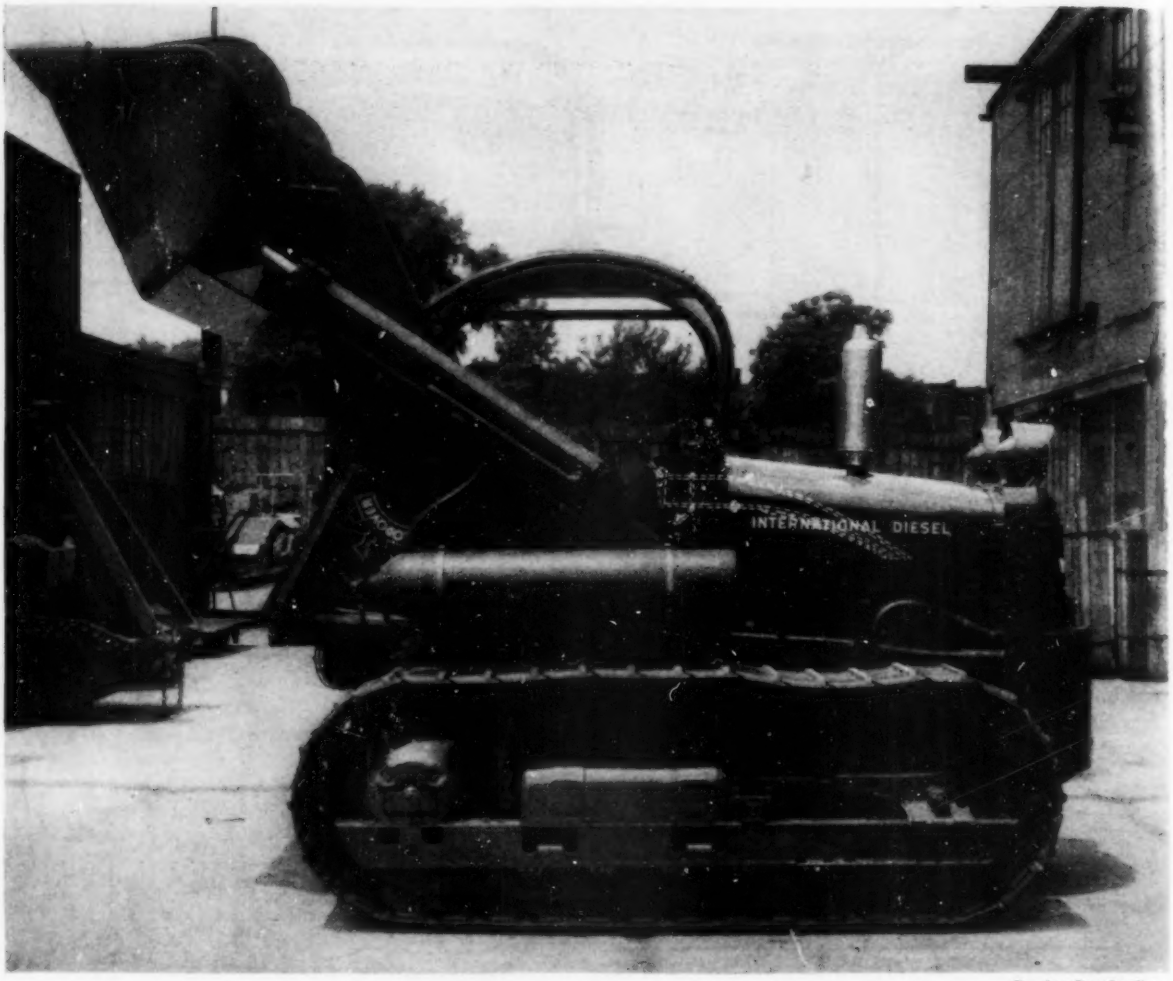
of previous models, the lever and bell crank system previously used to actuate the shuttle was found inadequate. The inertia of these heavy members made it impossible to achieve the 75 picks per min that were desired. A push-pull unit about 4 ft long with 180 total deg of bend now functions satisfactorily at this speed. Cost was not the governing factor. In fact, the manufacturer considers the new method more expensive, but is willing to accept this increase in view of the improved performance and precision.

The case cited is just one of several installations now in operation or under development. In each case, all factors were considered deliberately and impartially. The results of these studies proved that the push-pull has the positive advantages previously outlined but is subject to limitations as well. The efficiency, accuracy and low cost of levers for straight runs, for example, assure the latter of a permanent berth in this field.

In general, however, push-pulls become competitive when sizeable loads in tension and compression must be activated and the control path is complex, i.e. a series of bends are required. If the load is uni-directional, a simple cable of the choke-wire type or a push-rod may be adequate.

Although most heavy duty installations now in operation are limited to working loads of 50 to 60 lb, the present maximum limit is about 125 lb. Loads on aircraft door, such as the one shown in Fig. 2, are known to have exceeded 400 lb without damage when there is mis-alignment between the latches and receptacles.

Other factors that can make these new controls more desirable than the



Service Supply Corp.

Fig. 5—Loadover now uses push-pulls to replace vulnerable hydraulic lines in the hydraulic system that controls the movement of the bucket. Flexible casing is used here in preference to the rigid types to prevent damage by rocks or other falling debris.

types now being used include:

(1) Weight must be minimized.

(2) Control must be sealed from dirt or corrosive atmosphere.

(3) Relative motion exists between the two extremities of the control path such as might be encountered when a unit mounted on a tractor operates components that are located on a trailor unit.

(4) Vibration is present, as on a flexibly mounted engine.

(5) Temperature changes are such that thermal expansion precludes the use of levers. Tests have been completed successfully for the armed services at a range of —72 to 160 Fahrenheit.

(6) Precise control is required. All mechanical controls have some backlash or last motion when the load changes from tension to compression, or vice versa. Backlash for push-pull, depends on several variable factors, the most significant of which is the shape of the control path. However, some indication of the degree of precision that is now available can be obtained from Table I which was taken from a recent specification AN-C-157.

Types of Construction

The basic elements of all controls of this type are (1) a moving member or linkage and (2) an outer casing. Different types of linkages are now available. The unit shown in Fig. 3(a), consists of phosphor bronze bearings swaged on a steel cable, and is recommended by the manufacturer for light duty only. (See Table II). Medium and heavy duty versions, (b) and (c) are made of steel beads, alternately shaped as olives and tublets, strung on steel cable. The ends of the beads have a ball-and-socket design to provide the necessary flexibility. The cable carries all tensile forces and the beads form a solid column to support compressive or push loads.

Another type of linkage, Fig. 4 has an outer wire of comparatively large diameter wound around a main body of cable. The outer wire or helix reduces friction, particularly in bend areas. As with the type in Fig. 3, this design provides a reservoir for the lubricant needed.

Both types of linkage are available enclosed either in rigid conduit, flexible casing, or combinations of both Generally, a completely rigid run is recommended because of its lower cost, greater strength, easier installation, and wider latitude in the disposition of intermediate mounting brackets. In the earthmoving vehicle shown in Fig. 5, flexible casing was selected primarily because of the possibility of damage to rigid conduit by stones and other falling debris. In this installation, push-pulls operate hydraulic controls for the bucket. Previously, long,

vulnerable hydraulic lines were needed from the pump to the control valves in the cab and then to the operating cylinders. The new design permits the valves to be located adjacent to the pump in the front of the unit.

In general, however, flexible casing should be used only in cases where vibration or relative motion between control points is present. In such cases, it should be combined with the rigid type, if possible, and the flexible section should be kept as short as possible. Protective synthetic coatings can be applied to resist corrosion and chafing. These also serve to exclude moisture, oil, gasoline and most acids.

Fittings and Accessories

Push-pull controls are not limited to the transmitting of simple translatory motion. A wide variety of fittings and attachments have been developed to make them adaptable to many fields of application. Some typical units are shown in Fig. 6.

Control Layout

Controls can be obtained pre-formed and pre-assembled for installation on original equipment, or the various components can be ordered for assembly at the time of installation. The latter type is usually preferred for experimental models and small volume installations; the preformed and preassembled units may offer economic advantages when large production runs are involved.

Design and drafting time can usually be saved in laying out a control path by first locating both ends of the installation and then completing the remainder of the run. Experience has indicated a radius of five inches or more is recommended with rigid type conduit, although where necessary a radius of only three inches can be tolerated. These smaller radii, however, may introduce large friction forces. When flexible casing is used, the run should be bent with a radius of 6 in or larger.

Another consideration is the length of run. Controls as long as 25 ft, having four or more bends that total 360 deg are now operating successfully. Longer runs may be possible, but are not generally recommended since efficiency usually drops off when this limit is exceeded. The magnitude of drop is determined by the total number of degrees of bend.

Similarly, the range of strokes is arbitrarily set at $\frac{1}{8}$ to 14 in, but the average stroke in the use today is about 4 in. The maximum value listed is primarily one of providing enough straight section to allow the end of the control to function properly. Fittings like the radian unit and hobbed wheel that are illustrated in Fig. 6 can often be used to reduce this minimum-straight requirement.

Table III – What the Installation Engineer Must Know About Your Problem

1. Control will be mounted on a_____(type machine).
2. It will operate_____
3. The load the control will actuate is_____lb in compression and _____lb in tension.
4. The overall length of the control is_____in.; the total degrees of bend is_____
5. The length of stroke is_____inches.
6. Vibration is present as follows: (check one)
   None..... Moderate..... Severe.....
7. Does relative motion exist between the ends of the control?
   Yes?..... No?.....
8. Control is operated manually..... automatically.....
9. Casing required is rigid....., flexible....., combination.....
10. Will the control be exposed to severe service or corrosion?
    Yes..... No.....
11. The mount of backlash permitted is_____inches.
12. Control will be panel mounted_____ Other_____?

Conclusion

Based on the recommendations given previously, a superficial examination of a control problem can usually show whether or not a push-pull should be considered. A complete analysis of all economic and performance factors, however, is not obtained so readily. Because of the many variables involved, such as length, bends, type of construction, and fittings one or more of the manufacturers should be consulted. To facilitate this phase of the design, Table III lists the data a manufacturer must have to supply the desired information for nearly all industrial applications.

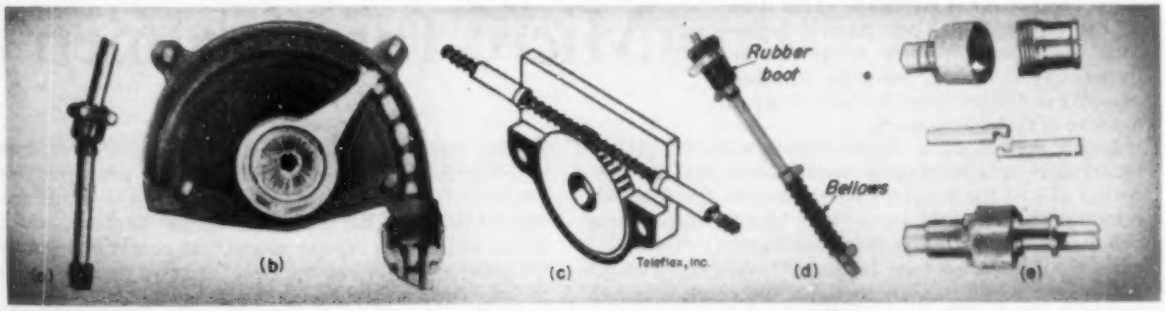


Fig. 6—Typical accessories to permit installations in many different types of products. (a) Swivel joint. Permits the control end to rotate approximately 9 degrees about its center line. This compensates for curvature when operating levers and also permits some relative motion to be present. (b) Radian Unit. Converts limited angular to straight line motion. (c) Hobbed wheel. Used with helix type construction in Fig. 4 and permits unlimited rotary motion. This unit can also be made with built-in reduction gears. (d) Waterproof fittings. Synthetic rubber boots and bellows protect controls from moisture, dirt, and most acids. (e) Quick disconnect. Can be used for firewall or similar type coupling.

Micro-Interferometry

R. E. SUGG
Mechanical Development Laboratory
E. I. du Pont de Nemours & Company

THE MICHELSON interferometry system applied to microscopic surface examinations has proved valuable as an accurate means for measuring fine finishes. It does not replace stylus instruments which now form the basis of surface roughness control. It does, however, take up where such instruments leave off—that is, in the examination of surfaces in which the irregularities are only a few millionths of an inch in depth. Stylus instruments are inadequate for these applications because:

1. The diamond stylus tip of approximately 0.0005 inches radius cannot reach the bottom of the fine scratches found on polished surfaces. This results in false traces and erroneous measurements.

2. The stylus tip produces high unit loading, of the order of 50,000 psi. with consequent scratching or burnishing of the surface. This may be unimportant for ordinary machined finishes but it cannot be tolerated on finely lapped or polished surfaces of such items as dies and the rolls used in plastic film and in metal foil manufacture.

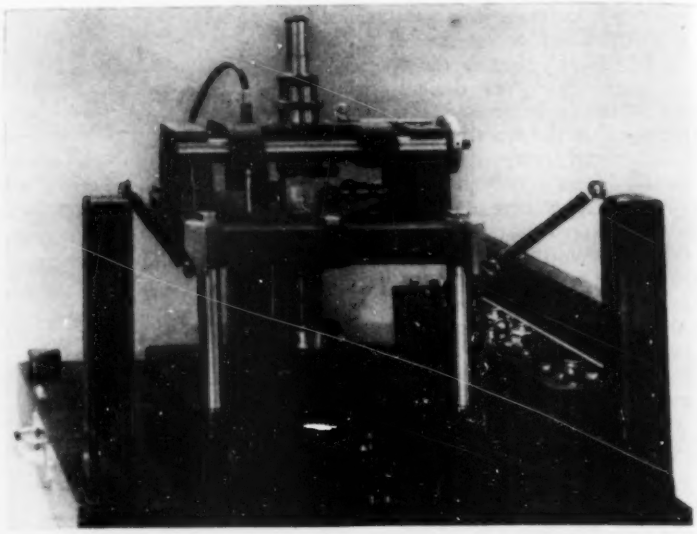


Fig 1—Michelson type micro-interferometer made by the Bausch & Lomb Optical Co. for measuring irregularities in lapped and polished surfaces.

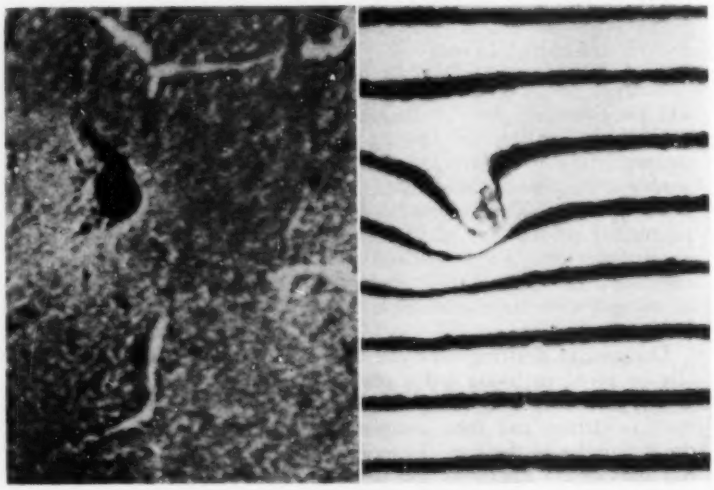


Fig 4—Photomicrograph (left) and interferogram (right) of a section of a finely lapped 440-A stainless steel roll. Mag. 200 X, enlargement 2½ X.

What is the Micro-Interferometer?

Fig. 1 is a photograph of a micro-interferometer which was made by the Bausch and Lomb Optical Company. Fig. 2 shows its optical arrangement. Monochromatic light is split by the prism into two beams, one of which is focused onto an optically flat reference surface by a microscope objective. The other deflected beam is focused onto the work surface by a matching objective. These beams are reflected by the two surfaces, and because of the wave nature of light, interference fringes, or contour bands, occur whenever their paths differ by a multiple of a half-wavelength. These contour bands are visible in the field of the microscope. Their interval represents elevation differences of 10 microinches, and it can be seen that scratches cause local fringe deviations which are a measure of the scratch depth.

Depth magnification, or distance between fringes, can be adjusted by a translating mechanism which shifts the optical axis of the reference mirror and its objective with respect to the rest of the instrument. Magnification through this means can be tremendous; for example, 100,000 X when the distance between fringes is 1-inch. Area magnification can be adjusted by changing the eyepiece and the objectives. It follows, when analyzing the profile lines, or interference fringes that there is no fixed relationship between the vertical and horizontal magnification of the profile, but usually high-power optics are used to resolve the scratches clearly.

The interferogram in Fig. 3 illustrates what is revealed by this means of examination. These profiles represent a diffraction grating ruled with 30,000 lines per inch. Since the irregularities extend about 0.4 of a fringe spacing, the depths of the individual rulings are about 4 microinches and since a regular geometrical profile is presented, the computation of the rms value is easy; it is 0.7 microinches.

Many commonly used surface finishes are even finer than the ruled grating mentioned above. Consider, for example, the 440-A stainless steel roll which is represented by the two illustrations of Fig. 4. This is indicative of a good mirror-like finish. The fringes in the interferogram show that the only appreciable defects in the surface are caused

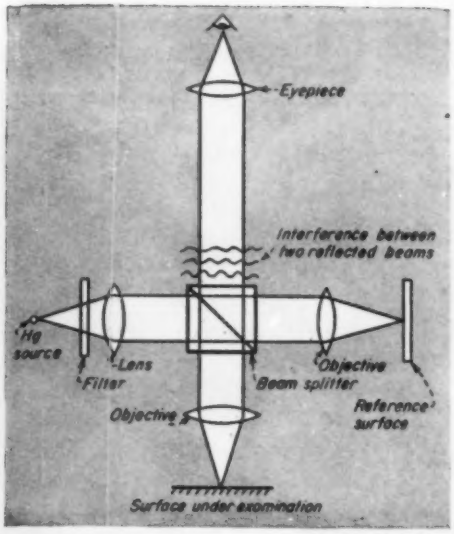


Fig 2—Diagramatic sketch of a micro-interferometer such as that shown in Fig. 1 at the left.

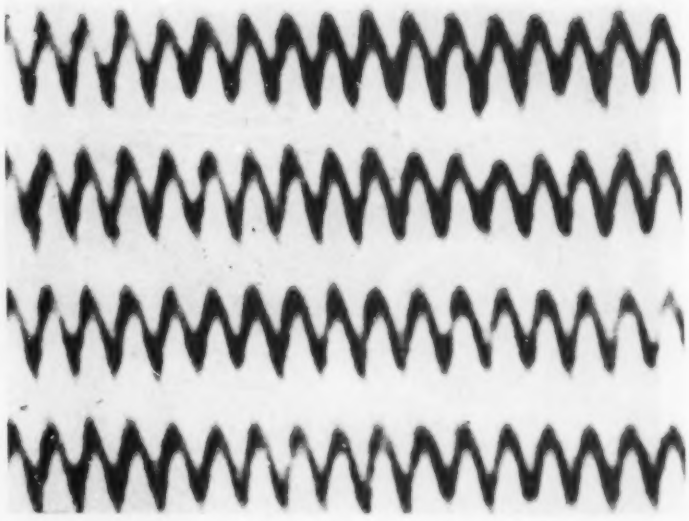


Fig 3—Interferogram of a 30,000 line in. diffraction grating. The computed rms value for this surface is 0.7 Mag. 1250 X, enlargement 5 X.

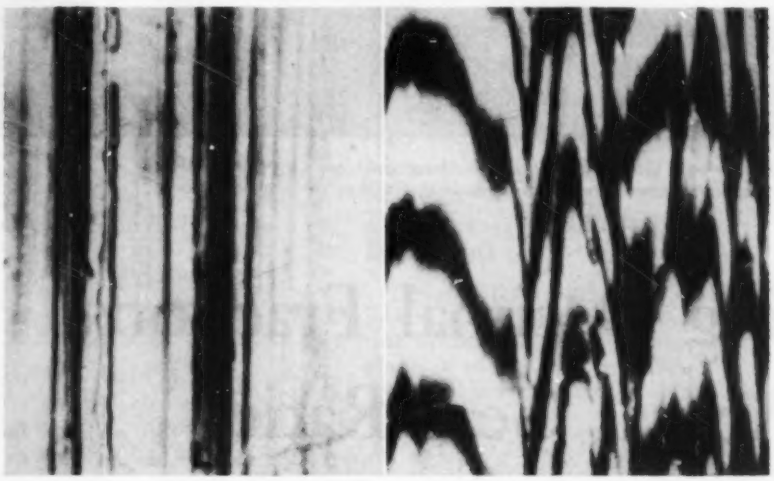


Fig 5—Photomicrograph (left) and interferogram of the same area of a 6 rms parallel bar. The rough profiles (right) show this is upper limit of micro-interferometry.

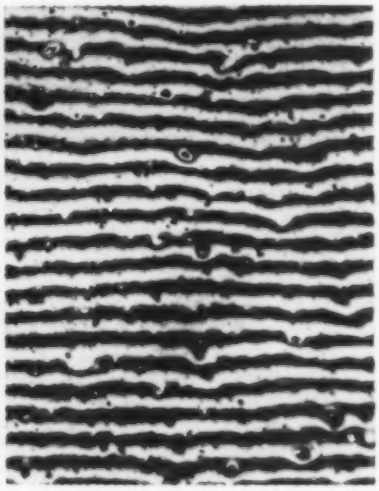


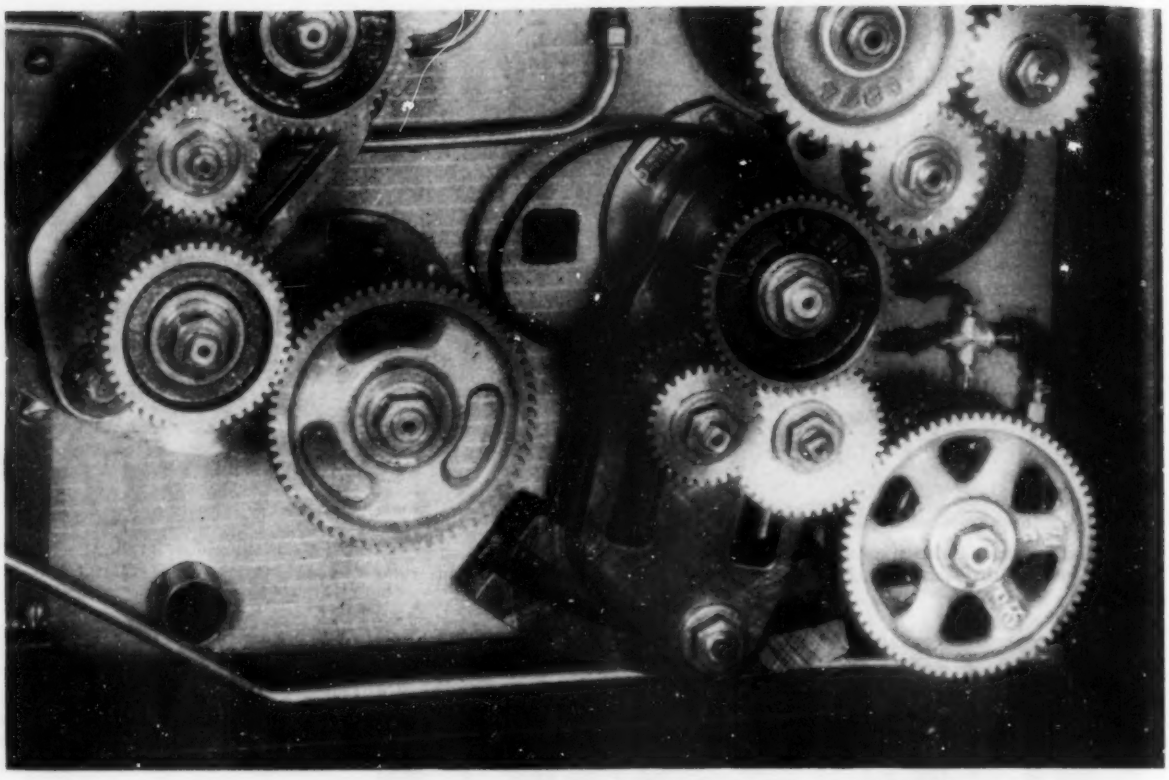
Fig. 6—Interferograms of a painted surface. Mag. 200 X, enlargement 2 X.

for Surface Measurements

by inclusions, which appear as dark spots in the photomicrograph, and which are polished or torn out to about 20 microinches below the surface. The rms value of a surface such as this is meaningless since isolated defects determine its quality.

As indicated in the introductory paragraph, micro-interferometric examination is usually applicable only to polished type surfaces. Rough surfaces become unreadable as illustrated by Fig. 5, which shows a photomicrograph of a finely ground machinists parallel bar and an interferogram of the same area. A trace of this surface with a stylus type surface measuring instrument indicated an rms value of 6 microinches, and yet the profiles as shown in the interferogram are exceedingly rough. This surface definitely represents the upper range of usefulness of the micro-interferometer.

The instrument is not restricted, however, to the examination of metal surfaces. Materials such as surfaces and vinyl films which are too soft to be examined by other means can be evaluated. For example, the interferogram in Fig. 6 revealed quantitative information about a painted film since the fringes show the heights to which the individual pigment particles are sticking up from the surface. However, a better idea of the value of micro-interferometry in non-metallic surface evaluation must await further development work in this field.



Change gear arrangement on a Gould & Eberhardt hobbing machine, a typical application requiring an accurate conversion from a decimal fraction to a gear ratio.

Converting Decimal Fractions To Actual Gear Ratios

GERALD SMITHSON

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IN THE DESIGN OF MECHANISMS, it is sometimes necessary to find a gear ratio that approximates a decimal fraction. For example, change gears for gear and thread cutting machines are frequently of this nature. If the accuracy required is not too great, this conversion can be accomplished simply by reference to a table of fraction-decimal equivalents[1]. All too often, however, a single pair of gears is not sufficiently accurate and recourse must be had to a train of gears (usually two pairs) to achieve accuracy.

A number of methods have been proposed for selecting such gear ratios. All these methods use trial and error procedures to determine common fractions that closely represent the required decimal. These fractions are then examined to see whether they are sufficiently accurate to fit the problem at hand. When the integers comprising the fraction are large, the numerator and denominator must be factorable into numbers that are practical for gear teeth.

The value of any method depends on the ease with which common fractions are discovered for trial purposes. The method of conjugate fractions speeds the process considerably.

Conjugate Fractions

Two fractions, a/b and c/d are said to be conjugate if the difference of their cross products is one; or,

$$ad - bc = \pm 1 \qquad (1)$$

If a/b is smaller than c/d, then:

$$ad - bc = -1 \qquad (2)$$

If a new fraction is formed from two conjugate fractions by adding the numerators and the denominators, this new fraction will be conjugate to each of the two fractions from which it was formed. For example, if a/b and c/d are conjugate, so that Eq (1) holds, then the fraction formed by adding the numerators and denominators is $(a + c)/(b + d)$. It can easily be verified that this fraction is conjugate to each of the two original fractions by taking the cross products. Thus, with respect to the fraction a/b:

$$(a + c)\,b - (b + d)\,a = bc - ad = \pm 1 \qquad (3)$$

The last part of this expression is recognized as a form of Eq (1). Checking for conjugacy with the other fraction, c/d, yields similar results.

Superscripts refer to listing at end of article.

Now it can be shown that the fraction $(a + c)/(b + d)$ not only lies between the two original fractions, a/b and c/d, but is also that fraction lying between them which has the smallest numerator and denominator. For if a/b is smaller than c/d, then the following expressions are true:

$$\frac{a}{b} < \frac{c}{d} \quad (4)$$

$$ad < bc \quad (5)$$

$$ad + ab < bc + ab$$

$$a(b + d) < b(a + c) \quad (6)$$

Therefore,

$$\frac{a}{b} < \frac{a + c}{b + d} \quad (7)$$

Similarly, by adding cd to both sides of Eq (5) it can be proven that:

$$\frac{a + c}{b + d} < \frac{c}{d} \quad (8)$$

From Eqs (7) and (8) then, the fraction $(a + c)/(b + d)$ lies between a/b and c/d. It remains to be shown that the fraction $(a + c)/(b + d)$ is the one with the smallest numerator and denominator so positioned. This is done as follows:

Assume that another fraction $(a + c - m)/(b + d + n)$ does lie between a/b and c/d where m is a positive integer and n is an integer which for generality may be either positive or negative. Then:

$$\frac{a}{b} < \frac{a + c - m}{b + d + n} \text{ and:} \quad (9)$$

$$\frac{a + c - m}{b + d + n} < \frac{c}{d} \quad (10)$$

Multiplying Eq (9) by $b(b + d + n)$ gives:

$$a(b + d) + an < b(a + c) - bm \quad (11)$$

$$a(b + d) - b(a + c) < -an - bm \quad (12)$$

But from Eq (3):

$$a(b + d) - b(a + c) = \pm 1$$

And, from Eq (6), which is true for $a/b < c/d$:

$$a(b + d) < b(a + c); \text{ therefore,}$$

$$a(b + d) - b(a + c) = 1 \quad (13)$$

Substituting Eq (13) in Eq (12):

$$-1 < -an - bm \quad (14)$$

This was arrived at by starting with Eq (9). Beginning with Eq (10), a similar development gives:

$$-1 < md + cn \quad (15)$$

From Eq (14), it is apparent that since m was assumed as a positive integer, n cannot also be a positive integer. Assuming the other alternative, let $n = -n'$ where n' is a positive integer. Eqs (14) and (15) become:

$$-1 < +an' - bm \quad (16)$$

$$-1 < +md - cn' \quad (17)$$

Now, Eq (16) requires that

$$an' \geqq bm \text{ or}$$

$$a/b \geqq m/n' \quad (18)$$

Similarly, Eq (17) requires that

$$m/n' \geqq c/d \quad (19)$$

The combination of Eqs (18) and (19) yields:

$$a/b \geqq c/d \quad (20)$$

But this contradicts the original assumption, Eq (4), that $a/b < c/d$. Therefore, the assumption made in Eqs (9) and (10), that there exists a fraction lying between a/b and c/d with a numerator smaller than $(a + c)$, has been shown to lead to a contradiction. It is, therefore, untrue. In a similar fashion, it can be shown that $b + d$ is the smallest denominator of any fraction lying between a/b and c/d. The fraction formed by adding the numerators and denominators is, therefore, the one with the smallest numerator and denominator that can be formed.

This is important in the work which follows, since it guarantees that by the simple process of adding the numerators and denominators of two conjugate fractions, the designer can discover all the fractions that lie between them and that might provide a solution.

Table of Fraction-Decimal Equivalents

Tables of fractions can be built up by the addition process just described that will include all the fractions between 0 and one. To illustrate, a short table has been prepared in which the maximum numerator or denominator is limited to 10. The table has been spread out horizontally in order to better demonstrate its development. See Table 1(a). Each fraction is formed by adding the numerators and denominators of adjacent fractions (i.e., fractions that are closest vertically and to the left. Thus the process is begun by forming $\frac{1}{2}$ from 0/1 and 1/1. Then $\frac{1}{3}$ is formed from 0/1 and $\frac{1}{2}$; $\frac{2}{3}$ is formed from $\frac{1}{2}$ and 1/1; $\frac{3}{5}$ is formed from $\frac{1}{2}$ and $\frac{2}{3}$ and so on.

When a summation produces a number greater than 10 the fraction is discarded. For example, the next fraction between $\frac{3}{5}$ and $\frac{5}{8}$ would be 8/13. Further development between these two fractions is therefore discontinued. It will be observed, however, that the final arrangement of the fractions, as shown in the left column of Table 1(b), preserves the condition that each fraction is adjacent either to a fraction from which it was formed or is adjacent to a fraction which it helped form. From these conditions it follows that every pair of adjacent fractions are conjugate.

The same is true for larger tables in which the numerator and denominator are limited to a maximum value of 100 or 120. Such tables, which also give the decimal equivalent of the fractions (as illustrated in Table 1(b)), are commonly used for finding gear ratios. The fact that adjacent entries are conjugate makes these tables a good starting point for finding more exact ratios using two pairs of gears. It should be noted, however, that conjugacy between adjacent entries will not necessarily exist in those tables in which fractions using integers *below* a certain value have been discarded.

A simple example will illustrate how to use the table to obtain more exact gear ratios. Suppose it is desired to obtain a set of gears equivalent to the decimal 0.52819. From a table of equivalent fractions, the following are obtained:

$$\frac{47}{89} = 0.528090$$

$$\frac{28}{53} = 0.528320$$

For change gears, the usual requirement is an accuracy within five units in the fifth decimal place. Therefore, neither of the above fractions is close enough. The addition of the numerators and denominators yields:

$$\frac{47 + 28}{89 + 53} = \frac{75}{142} = 0.52817$$

which is within the required limits. The fraction obtained can be resolved into convenient ratios for two pairs of gears, as follows:

$$\frac{75}{142} = \frac{3 \times 25}{2 \times 71} = \frac{60 \times 25}{40 \times 71}$$

The above example was of course chosen so it would come out very sim-

The method of conjugate fractions saves much cut-and-try in solving problems such as:

Select a gear train with a ratio of 3.92763 and a 0.00002 tolerance

Table I—Decimal Equivalents of Some Common Fractions

(a) — Origin of Fractions	(b) — Decimal Equivalents
0/1	0.000 000 00
1/10	0.100 000 00
1/9	0.111 111 11
1/8	0.125 000 00
1/7	0.142 857 14
1/6	0.166 666 67
1/5	0.200 000 00
2/9	0.222 222 22
1/4	0.250 000 00
2/7	0.285 714 29
3/10	0.300 000 00
1/3	0.333 333 33
3/8	0.375 000 00
2/5	0.400 000 00
3/7	0.428 571 43
4/9	0.444 444 44
1/2	0.500 000 00
5/9	0.555 555 56
4/7	0.571 428 57
3/5	0.600 000 00
5/8	0.625 000 00
2/3	0.666 666 67
7/10	0.700 000 00
5/7	0.714 285 71
3/4	0.750 00 00
7/9	0.777 777 78
4/5	0.800 000 00
5/6	0.833 333 33
6/7	0.857 142 86
7/8	0.875 000 00
8/9	0.888 888 89
9/10	0.900 000 00
1/1	1.000 000 00

ply in order to illustrate the method. Suppose, now, a case is considered in which more steps must be taken before a suitable answer is obtained. Assume gears are required which will give a ratio of 3.92763 with a ± 0.00002 tolerance.

To use the method under discussion, it is necessary to take the reciprocal of this number to bring it within the range of fractions between zero and one. When the proper gears have been found, invert the ratios to obtain the number desired. Introducing the tolerance into the reciprocal, the fraction must lie between

$$\frac{1}{3.92765} = 0.2546052 \text{ and}$$

$$\frac{1}{3.92761} = 0.2546078$$

The nearest fractions to these decimals, using numbers of 100 or less are

$$\frac{14}{55} = 0.2545455 \text{ and}$$

$$\frac{13}{51} = 0.2549020$$

Neither of these is close enough. By the addition of the numerators and denominators, the following is obtained:

$$\frac{14+13}{55+51} = \frac{27}{106} = 0.2547170$$

This last fraction is still not within the required limit. It is, however, conjugate to both the fractions 14/55 and 13/51. Therefore, a second addition can be performed with either of the latter to form new fractions. Now, if 27/106 is added to 13/51, it can be predicted that the new fraction will lie between 0.2547170 and 0.2549020. It is obvious that these computations are going in the wrong direction to get within the required interval. So, the next addition should be made with 14/55. Thus,

$$\frac{27+14}{106+55} = \frac{41}{161} = 0.2546584$$

which still fails to come within the required limits. However, before performing another addition, it should be observed that for each addition the fraction 14/55 is used. This first part of the work can be condensed by finding out how many additions are necessary to bring the generated fraction to the edge of the required interval. If this number is n, it is possible to set up the equation:

$$\frac{13+n\,14}{51+n\,55} = 0.2546078 \qquad (21)$$

By solving for n, it is found that:

$$n = 4.4$$

Substitution of $n = 4$ in Eq 21 yields

$$\frac{13+(4\times 14)}{51+(4\times 55)} = \frac{69}{271} = 0.2546125$$

This is a little larger than the required interval. Using $n = 5$, or simply adding the numerators and denominators of the fractions 14/55 and 69/271 together results in:

$$\frac{69+14}{271+55} = \frac{83}{326} = 0.2546012$$

This is also outside the required interval, but on the other side. Now by adding the numerators and denominators of these last two fractions, the following is arrived at:

$$\frac{83+69}{326+271} = \frac{152}{597} = 0.2546064$$

This fraction is now within the required limits. It cannot, however, be factored into suitably sized gears.

A chart, Table II, shows a summary of the steps taken so far. The required interval is indicated by bracketing the appropriate decimals. The order in which the several steps are taken are indicated by their alphabetical designations. Thus, the two fractions taken from the table of decimal-fraction equivalents are labelled (*a*) and (*b*). The first two fractions which closed in on the interval are labelled (*c*) and (*d*). And the summation performed with these fractions is labeled (*e*). Referring to Table II, it is seen that there is a choice in taking the next step. Either (*e*) and (*c*) or (*d*) and (*e*) can be added together. If the latter combination is chosen, the following is obtained:

$$\frac{83+152}{326+597} = \frac{235}{923} = 0.2546046$$

which is outside the required limits. Adding this fraction to 152/597 again produces:

$$\frac{235+152}{923+597}=\frac{387}{1520}=0.2546053$$

This once more is inside the required limits. Factoring the numerator and denominator of this fraction,

$$\frac{387}{1520}=\frac{3\times3\times43}{2\times2\times2\times2\times5\times19}$$

This expression can be converted to a train of four gears in many ways. One such arrangement would be (27 x 43)/(60 x 76). Since the ratio desired is the reciprocal of this ratio, a final solution is:

$$3.92763\pm.00002=\frac{60}{27}\times\frac{76}{43}=3.927649$$

Had this last fraction failed to factor into suitable gears, the process could have been continued. At this point, there is the advantage that having obtained two fractions, both of which are inside the required interval, the addition of adjacent fractions will always produce fractions which likewise are within the required interval. Thus by taking the two fractions, 387/1520 and 152/597, which are conjugate, the designer can obtain the additional solution:

$$\frac{387+152}{1520+597}=\frac{539}{2117}=\frac{7\times7\times11}{29\times73}$$

$$=\frac{33}{87}\times\frac{49}{73}=0.2546056$$

The reciprocal of this number is 3.927644, well within required limits.

Table II—Initial Steps

Step	Formed From:	Fraction	Decimal
(a)	Table of Fractions	14/55	0.2545455
(d)	(a) and (c)	$\frac{69+14}{271+55}=\frac{83}{326}$	0.2546012
(e)	(d) and (c)	$\frac{83+69}{326+271}=\frac{152}{597}$	[0.2546052] 0.2546064 [0.2546078]
(c)	(a) and (b)	$\frac{13+4\times14}{51+4\times55}=\frac{69}{271}$	0.2546125
(b)	Table of Fractions	13/51	0.2549020

Table III—Complete Solution

Step	Formed From:	Fraction	Decimal	Gear Train
(a)		14/55	0.2545455	
(d)	(a) and (c)	$\frac{69+14}{271+55}=\frac{83}{326}$	0.2546012	
(f)	(d) and (e)	$\frac{83+152}{326+597}=\frac{235}{923}$	0.2546046	
(g)	(f) and (e)	$\frac{235+152}{923+597}=\frac{387}{1520}$	0.2546052 0.2546053	$\frac{60}{27}\times\frac{76}{43}$
(h)	(g) and (e)	$\frac{387+152}{1520+597}=\frac{539}{2117}$	0.2546056	$\frac{87}{33}\times\frac{73}{49}$
(e)	(d) and (c)	$\frac{83+69}{326+271}=\frac{152}{597}$	0.2546064 0.2546078	
(c)	(a) and (b)	$\frac{13+4\times14}{51+4\times55}\quad\frac{69}{271}$	0.2546125	
(b)		13/51	0.2549020	

A summary is given in Table III of all the steps taken. These are indicated, as in Table II, by their alphabetical designations. It will be noted that there are still some unexplored areas which might yield a solution had one not yet been found. To explore the area between (*e*) and the upper limit of the required interval (0.2546078), (*e*) and (*c*) would be combined until a decimal inside the required interval was obtained.

Conclusions

From the example given above, it is seen that the method of conjugate fractions is a simple yet efficient way for discovering fractions which are potential solutions to the problem. It is true that by adding the numerators and denominators of any two fractions, a new fraction will be formed which in value lies between the two original ones. But if the two original fractions are not conjugate, the new fraction will not be the one with the smallest numerator and denominator and many fractions which are potential solutions will be overlooked. If the accuracy required is high, suitable solutions will generally be hard to come by and the failure to discover fractions with low numbers which are possible solutions may lengthen the work considerably.

The method of continued fractions[2] does not always lead to a solution[3]. On the other hand, the method that utilizes a table of logarithms of fractions[4] is a hit-or-miss proposition. Insofar as accuracy is concerned, it is no better than using a table which gives the decimal equivalents of ratios, rather than their logarithms. In fact, if a calculating machine is available, it is much simpler to just assume one gear ratio, divide the required number by this ratio, obtaining thereby a new decimal. Then, consulting the table of fraction-decimal equivalents, the nearest fraction to this latter decimal is found. If a close enough answer is found on the first try, it is just coincidence. If a high degree of accuracy is required, a considerable amount of time may be spent getting nowhere. And using logarithms of the ratios instead of the decimal equivalents themselves, does not alter this situation.

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2. Canick, L. N., "Calculation of a Practical Gear Ratio Approximately Equal to a Given Decimal," *Product Engineering*, January 1950, p. 112.

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4. "Finding Four-Gear Ratios," *Machinery's Handbook*, 14th Edition, p. 1169.

How to Design Parts that Assemble

Methods of joining tubes, sheet metal and machine parts i

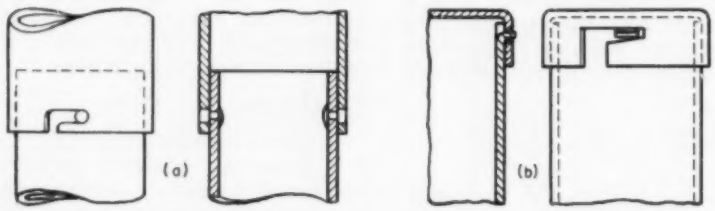


Fig. 1—(*a*) Telescope-type joint uses headless bayonet pin to assemble tubes. Method can also be used to fasten cover on cylindrical member. (*b*) Pins such as those in (*a*) can be eliminated by using formed tabs.

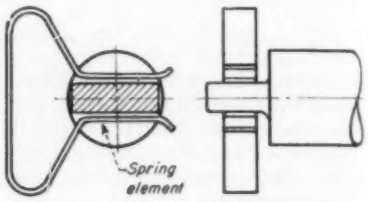


Fig. 2—Rotating cylindrical member 90 deg forces spring elements apart and results in a clamping force on milled section

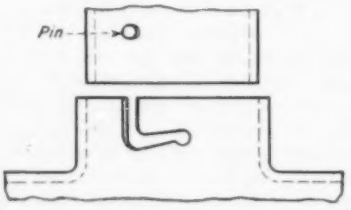


Fig. 6—Two diametrically opposite pins engage slots in lower member. Slot has slight incline with recess to provide a locking tendency. This method can provide leak proof sealing.

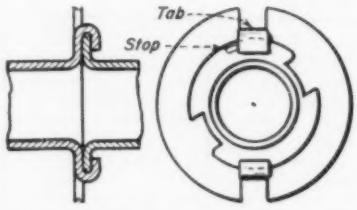


Fig. 7—Tubes of equal diameter are joined by engaging tabs in slots and twisting. Provides means of quick assembling and disassembling without bending tabs each time.

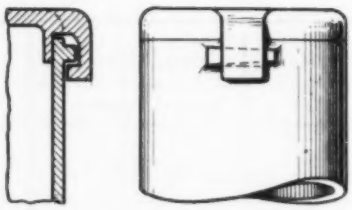


Fig. 8—Tapered projections on diametrically opposite sides of cast structure engage tabs on cast cover to provide for clamping cover tightly. Machined pins can replace the tabs.

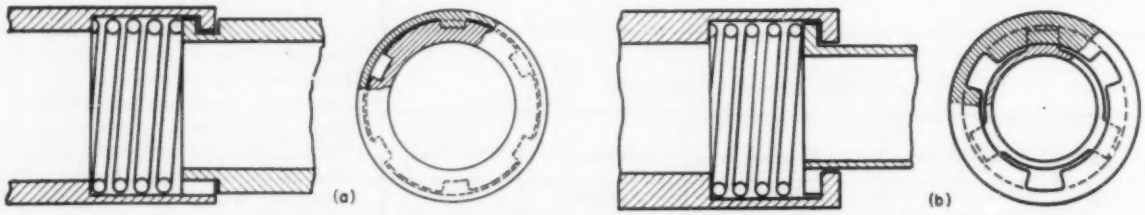
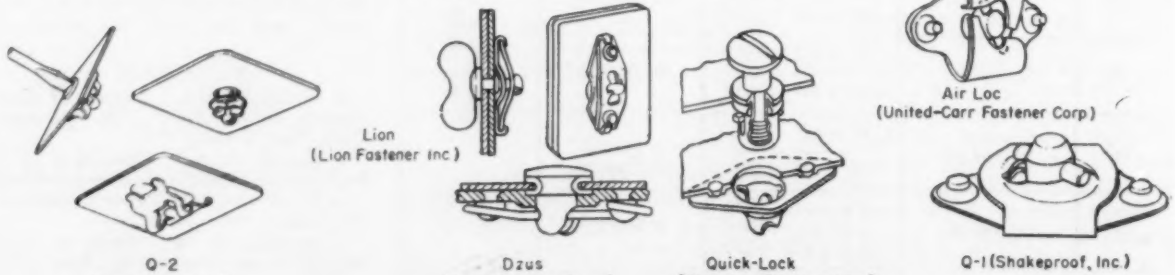


Fig. 12—Two different versions of a spring-loaded type coupling for metal or plastic tubing. In both cases, the two parts can be assembled or disassembled by twisting one of the elements. In sketch (a), the holding tabs are located on the larger member and the receiving slots are on the smaller one. In (b), the relative positions of tabs and slots are reversed.

QUICK-RELEASE FASTENERS that engage or disengage with a partial twist as contrasted to fasteners that require several turns for complete engagement or disengagement.



and Lock by Twisting

assemblies that engage and disengage with a twist of one element.

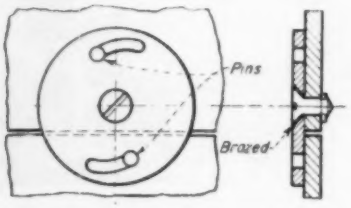


Fig. 3—Spiral type slots force pins to pull two elements together. Recesses at ends of slots serve for locking.

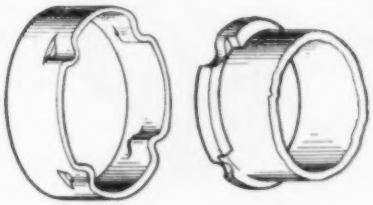


Fig. 4—Formed projections on cover engage recesses in flange of cylindrical vessel. Taper on flange provides locking.

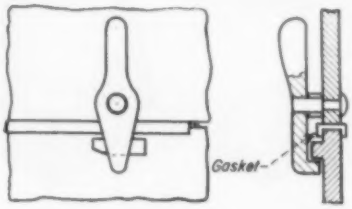


Fig. 5—Wedge principle can also be used for locking vent windows on cars or fastening two metal sheets.

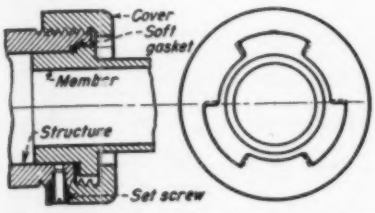


Fig. 9—Structure and cover are cut away in three places to receive projections on member. Rotating cover 60 deg permits member to be inserted or removed. Set-screw provides means for locking cover.

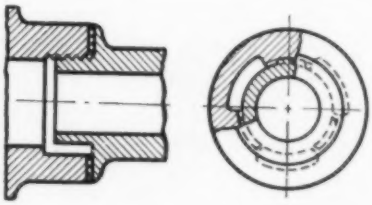


Fig. 10—Intermittent threads on both members require only a partial revolution for complete engagement. Tightness of joint can be controlled within limits by varying the thread lead.

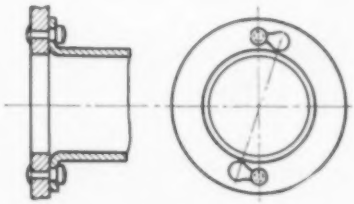


Fig. 11—Flanged tube is fastened to plate by twisting. Bayonet-type pin with head engages slot in tube. Seal can be made leak-proof by spring-loading the pin and adding a soft gasket.

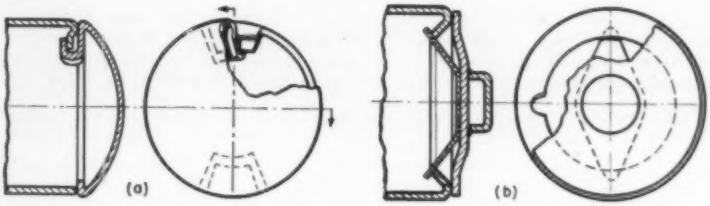


Fig. 13—Two other methods of attaching covers to cylindrical vessels. In *(a)* flanges on structure hold the cover tightly after it has been engaged and rotated. Elongated tabs are used in *(b)* to mate with notches in the structure.

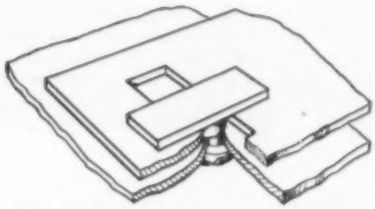
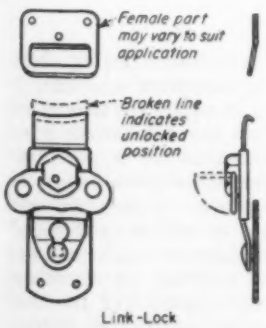
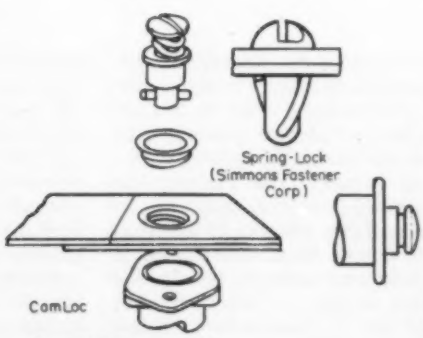


Fig. 14—Method of fastening a member to a structure by twisting a third element through a 90 degree arc.





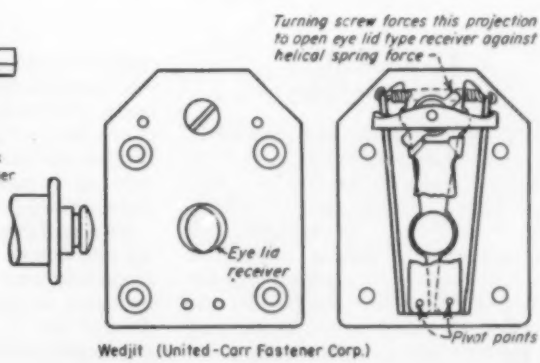

Turning screw forces this projection to open eye lid type receiver against helical spring force
Eye lid receiver
Pivot points
Wedjit (United-Carr Fastener Corp.)

Fig. 1—Chromizing of ferrous parts does not increase dimensions because chromium displaces an equivalent amount of base material. As long as chrome-rich powder can be packed against surfaces, shape of parts is no limitation. Thus, threads and complex sections can be treated.

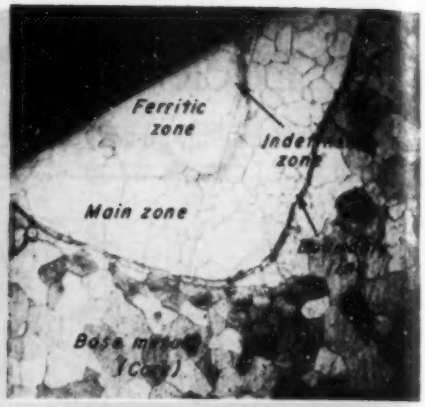


Fig. 2—Oblique section through ¾-in. dia mild steel rod shows 0.0040-in. chromized coating and base metal with boundary line between. Magnification: 0 55X.

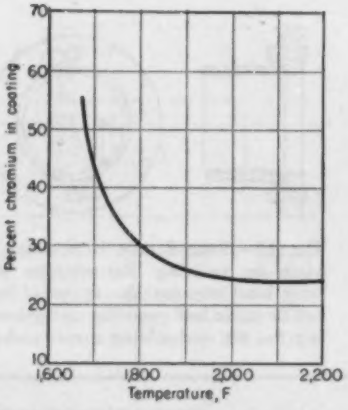


Fig. 3—Average chromium content of coating formed on low carbon steels is from 24 to 26 percent if chromized above 1,900 Fahrenheit.

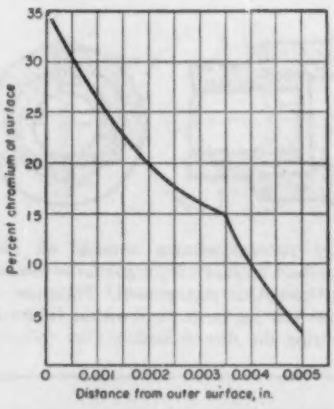


Fig. 4—Chromium concentration decreases in proportion to distance from outer surface. Break in curve is at coating-core boundry.

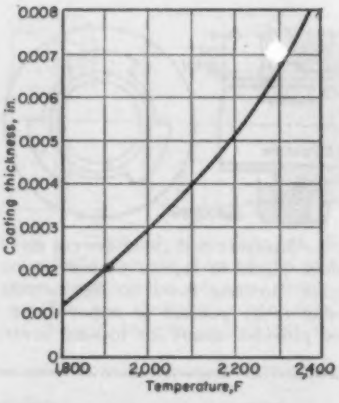


Fig. 5—Thickness of coating increases slightly when process temperature is set at successively higher levels during 4½-hr. heat.

Hard Chromium Coatings

G. A. SAMUEL
Diffusion Alloys Corporation

BOTH PLAIN CARBON and alloy steels, as well as cast iron, can be made heat, wear and corrosion resistant by a low-cost English process called Chromizing. Similar to conventional pack carburizing, the process consists of placing parts in a carburizing box containing a chrome-rich powder and heating the sealed box in an ordinary furnace for six to twelve hours.

The surface alloy that forms on the parts falls within the category of high-chromium steels, yet it is not a substitute for stainless. Nor is it a replacement for chrome plating. Its field of application, Table I, is between those of stainless and plating, and slightly overlaps in each case.

The desirable features of chromizing are derived from an exchange of atoms between the chrome powder and the steel or iron. Chromium, thus diffused into the base metal, becomes an integral part of the base metal and therefore cannot peel, as is sometimes experienced with chrome plating. Not only does the chromium penetrate, it also displaces an equivalent amount of the ferrous base material, thereby leaving the dimensions of a part unchanged. This feature permits application of the process to precision and intricate parts, as well as to threaded sections and fasteners such as bolts and nuts. In addition, the chromium fills the smallest "pores" of the base surface, resulting in a smooth polishable finish. Fig. 1 shows typical parts.

The unetched layer or coating at the

Table I—Adaptability of Chromizing to Various Components as Compared to Chromium Plating and Stainless Steels

Type of Component	Chromium Plating	Chromizing	Stainless Steels	
			18-8	Chromium Iron
PROTECTION AGAINST HIGH TEMPERATURE SCALING				
Oil stove burner plates, gas jets and control fittings	Flakes	Withstands sulphur vapors and heat to 1,650 F	Sensitive to thermal shock; attacked by sulphur vapors	Difficult to form
Toaster and heat exchanger parts	Flakes	Satisfactory and economical	Satisfactory but expensive	Satisfactory but expensive
Bolts, nuts and tubing for heating devices	Flakes	Easily machined from mild steel	Difficult to machine and expensive	Satisfactory but expensive
Gear jigs for cyanide heat treatment	Flakes	Satisfactory and economical	Difficult to machine and sensitive to thermal shock	Satisfactory but expensive
Exhaust manifolds and baffle plates	Flakes	Withstands exhaust and sulphur vapors; easy to form	Sensitive to sulphur vibration and thermal shock	Withstands sulphur vapors, but not vibration and thermal shock
PROTECTION AGAINST AQUEOUS CORROSION				
Chains, conveyor links, meter bodies, pump parts, filter elements, steam turbine fasteners and buckets, tractor parts	Flakes	Easy to machine, weld and form	Satisfactory but expensive	Satisfactory but expensive
Hardware and processing equipment in corrosive media	Decorative but subject to corrosion after long exposure	Not as decorative as chrome plating, but resistant to corrosive media	Satisfactory but expensive	Resists sulphur vapors, but sensitive to thermal shock and vibration
PROTECTION AGAINST WEAR AND ABRASION				
Bearings and knife edges for scales; saw blades	Flakes; not as hard as chrome carbide	Low coefficient of friction, hardness to 70 Rc	Not applicable	Not applicable
Oil burner orifice plates	Not applicable	Satisfactory	Sensitive to sulphur vapors	Satisfactory but expensive
Dies for plastics and pressure castings, files, drills	Flakes	Satisfactory	Not applicable	Not applicable

for Ferrous Parts

surface of a chromized part is sharply separated from the core as shown in the photomicrograph, Fig. 2. The depth of diffusion is the degree to which chromium penetrates the coating alone, not beyond the apparent boundary between coating and core.

The microstructure shown in Fig. 2 is that of a $\frac{3}{8}$-in. dia mild steel rod, chromized to a coating depth of about 0.004 in. The section, taken obliquely through the coating and etched in copper chloride, consists of three zones: (1) An outer ferritic zone; (2) an indefinite, darkly-etched zone, through which the ferrite grains continue to the inner zone; and (3) an inner or main zone of the coating.

The average chromium content of the coating is from 24 to 26 percent for treatment temperatures between 1,900 and 2,050 F. At lower temperatures the average content is slightly higher. Fig. 3 shows a rapid rise of content as temperature is decreased from 1,850 Fahrenheit.

A curve of chromium concentration as a function of distance from the outer surface of the base material is plotted in Fig. 4. From a surface concentration of 35 percent chromium, the concentration decreases along a steep gradient to about 15 percent which is the coating-core boundary.

The rate of chromizing can be measured by the rate of increase in coating thickness or by the rate of chromium uptake. Since the average chromium content of the coating, and the concentrations at the surface and inner boundary are essentially constant, the curves obtained by plotting thickness against time, or total chromium uptake against time, Fig. 5, can be considered identical.

Effects of Alloying Elements

Chromium being a strong carbide-forming element, the carbon content of the base material becomes an im-

portant factor. The effect of carbon on the iron-chromium system is to widen the gamma loop and to form a series of mixed carbides that coexist with the alpha phase. During the chromizing operation, carbon migrates toward the coating and the carbide barrier that forms reduces the rate of chromium diffusion. The final carbon content of the coating can be as much as eight times that of the original steel.

The average chromium content of the coating also increases with increasing carbon in the steel. The lower rate of diffusion allows the build-up of a higher chromium concentration at the extreme surface.

With high carbon steels, a thin hard coating containing up to 60 percent chromium on the surface can be obtained. This coating is almost entirely chromium carbide. In the case of alloy steels, the various non-carbon additions can alter both the surface reaction and the rate of diffusion. Certain elements such as sulphur and phosphorus can pass into the diffusion area and "poison" the chrome-rich coating. Alloy steels of low sulphur and phosphorus content are therefore recommended.

Manganese and nickel favor the formation of austenite and hence have the effect of widening the gamma loop and increasing the chromium concentration required to form ferrite at processing temperatures. Since chromium diffuses slowly in austenite, the coating produced is thin and the chromium concentration relatively high.

Silicon induces ferrite formation and has the opposite effect to that of manganese. Deeper coatings are produced with lower chromium content. If 5 percent silicon is present, the material is ferritic at chromizing temperature, and the resultant coating is relatively deep.

The presence of chromium in the steel, since it is a ferrite-forming element, increases the rate of chromium diffusion. A 13-percent chromium iron remains ferritic. Chromium-carbon-iron alloys behave like carbon steels of similar structures when in the annealed condition. For example, a cutlery stainless steel containing 14 percent chromium and 0.35 percent carbon, which is about eutectoid composition, has the characteristics of steel containing 0.9 percent carbon. The coating in both cases is hard, thin and consists mainly of chrome carbide.

Selection of Coating

Since a chromized coating can prevent scaling and aqueous corrosion, or reduce wear and abrasion when applied to most grades of steels and ferrous castings, the type of coating required for a given application depends on the environment in which a part functions.

Most of the parts treated to date are made of mild steel. These resist scaling at temperatures to 1,650 F for an indefinite period and generally are not attacked by aqueous solutions. Table II shows the exception.

In heat resistant applications using low carbon steels, the chromium concentration should be high and penetration low for temperatures to about 1,650 F. Parts like mufflers are treated while flat at 1,700 F. The resulting 0.001 to 0.002-in. coating is highly ductile and treated sheets can be bent, riveted, hammered, pressed or stamped, and cold rolled to considerable elongation.

At temperatures above 1,650 F, a 0.002 to 0.004 in. coating is built up by heating parts at 1,800 to 1,850 F for extended periods. The resulting coating is less ductile than the thinner layer noted above, but forming operations are still practical.

When alloy steels, such as those containing molybdenum, are used to obtain high tensile strengths as well as resistance to scaling, the treatment temperature is about 1,930 F. A small amount of aluminum is added to the chrome-rich powder to stabilize the diffusion process.

For mild-steel applications requiring resistance to wet corrosion, treatment temperatures vary between 1,700 and 1,980 F and coating thicknesses from 0.001 to 0.005 in. The thickness and carbon content of the parts and steels involved are the determining factors.

Occasionally, ultra-high resistance to corrosion is desired. In such instances, straight chrome steels are used and the treatment limits just mentioned applied. The desirable feature thus obtained is a very high chromium concentration at the surface of the part treated.

When ferrous castings are chromized, some sacrifice in corrosion resistance has to be taken. This is the result of structural porosity, which can, after extended periods of heating and chromium diffusion, be partially overcome.

Resistance to wear and abrasion is usually achieved by coating medium carbon steels (0.030 to 0.045 C) to a depth of about 0.002 in. Surface hardness is 68 to 70 Rc, but hardness of the core is 40 to 45 Rc after heat-treatment.

On high carbon steels, a 0.015-in. coating has high surface hardness of 68 to 70 Rc when in the annealed condition. Relatively thick parts subject to high unit loading are heat treated after chromizing to develop a core hardness of 60 to 65 Rc, which is sufficient to support the hard skin. This outer surface has a low coefficient of friction, so that such a treatment is ideal for parts that must be protected against friction wear and abrasion, as well as resist shock and vibration.

Table II—Relative Corrosion Resistance of Chromized Materials to Various Agents

Base Material	Atmosphere	Alkali & soap water	Tap water	Salt water	Dilute HNO_3	Dilute HCL	Dilute H_2SO_4	Bleaching solutions	Food acids
Pure Iron	G	G	G	G	G	L	N	P	G
Low Carbon steel (0.15% C. max)	G	G	G	G	G	L	N	L	G
Low carbon steel (0.25% C. max)	G*	G	G*	P	G*	N	N	N	P
Medium carbon steel (0.25–0.6% C)	G	G	G	P	G	N	N	N	P
High carbon steel (0.6–1.2% C)	G	G	G	P	G	L	N	N	P
Homogeneous cast iron (Meehanite type)	G	G	G	P	G	L	N	N	P
Malleable castings	G	G	G	P	G	N	N	N	P
Cast Iron	P	P	P	L	P	N	N	N	L

* Limited resistance to sulphur bearing steels; otherwise this table does not allow for effects of alloying elements.
Key: G—Good resistance; P—Partial resistance; L—Low resistance; N—Not resistant.

Some Newer Organic Protective Coatings

DAVID BUSKER
Better Finishes and Coatings, Inc.

Recent developments in the field of protective coatings

Outstanding properties of the resin base finishes

Industrial applications

Specialty finishes

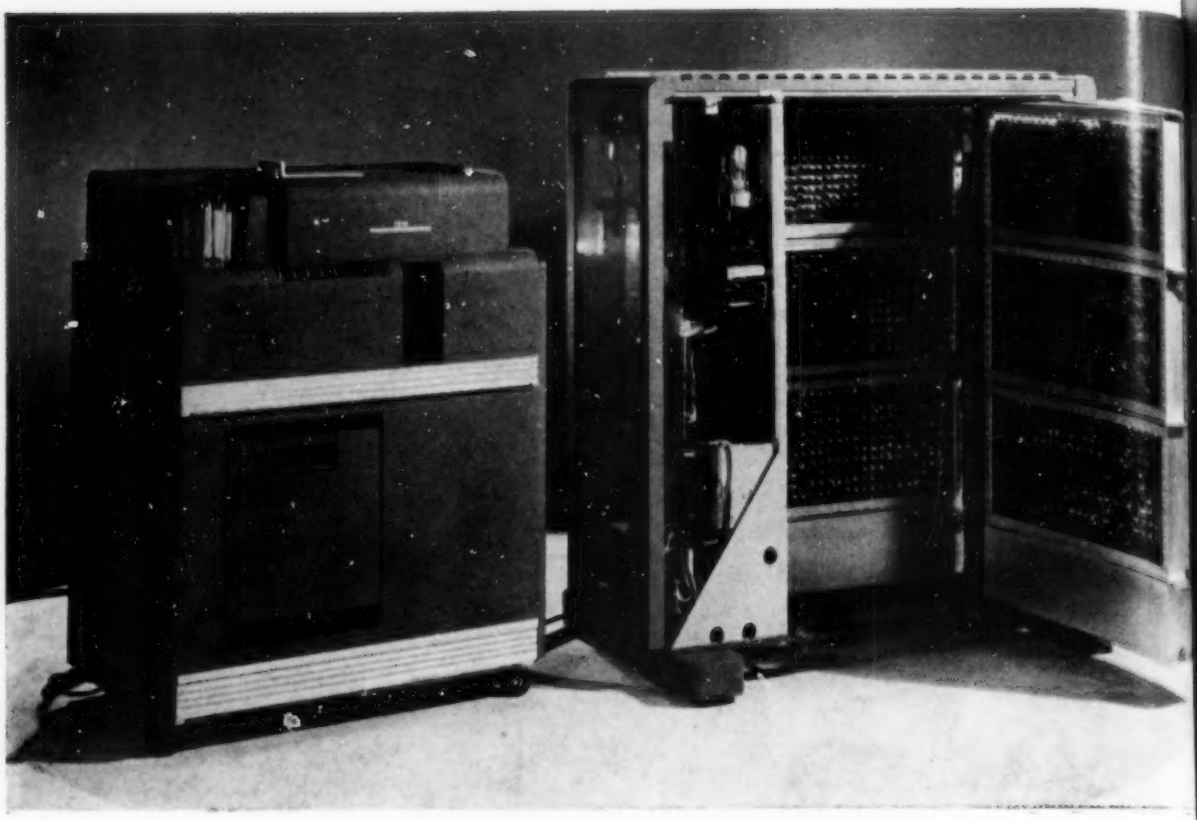
Strippable films

Bakelite Division
Union Carbide and Carbon Corp.

The need for more effective and prolonged protection of metal surfaces has stimulated the development of newer coating materials. Organic coatings and films are finding extensive use in this field because they have

1. Good corrosion resistance.
2. High heat resistance.
3. Resistance to moisture and chemicals.
4. Oustanding flexibility and adhesion.
5. Good abrasion resistance.
6. Good color retention.

Among the newer types of materials developed for protective coatings are the resins or film formers. These include the alkyds, ureas, melamines, chlorinated rubbers, vinyls, polystyrene, epon resins, silicones, polyethylene, acrylics and others. In many cases a combination of these resins is used in the coating formulation to obtain the advantages of each.



Business machines and equipment like the above electronic calculator are coated to provide surface protection from constant handling and to give a pleasant appearance. A urea-alkyd resin primer was used on this machine. International Business Machines.

The use of the organic coatings is not confined to solely protective purposes. A variety of colors can be obtained, including specialty finishes such as wrinkle and hammertone finishes. The combinations of colorability and protectiveness make the organic coatings suitable for many industrial and consumer applications.

A review of some of the more recent developments in the field of protective coatings is presented in this article.

Alkyd Resins

The alkyd resins are perhaps the most common of the filmformers used in the coating industry today. Chemically, they are the result of an interaction between a polyhydric alcohol (glycerine) and a polybasic acid (phthalic acid anhydride), and are generally fluxed with a vegetable oil or a fatty acid. In certain instances fish oil may be substituted for a vegetable oil.

The vegetable oil may be any one or a combination of linseed, soya, tung, castor or coconut oil. If coconut oil is used the alkyd resin is said to be "non-drying". Therefore, it is modified with other resins such as urea-formaldehyde or melamine, and drying is effected only by heat-curing at high temperatures. Non-drying alkyds are generally used in finishes for kitchen appliances where non-yellowing after baking is prerequisite. The air-drying alkyds are generally used in air-drying enamels but can also be heat-cured.

Alkyd resins as a group are characterized by being sticky and balsamic in nature, amber to straw in color, having a mild odor, and exhibiting the properties of extremely high gloss, good weathering, and gloss retention over long periods of exposure. They adhere excellently to most substrates. When properly pigmented, attractive finishes of high depth and lustre can be obtained in any desired color. Alkyd enamels can be applied by spray, brush, dip, roller coat or any other desired method of application.

During and since the last war, alkyds as film formers have been specified by the government for use in primers and enamels for tanks, trucks and other Army equipment. For example, U. S. Ordnance Specification MIL-E-11237 calls for the use of an alkyd resin in a lustreless olive-drab enamel; Specification 3-174 specifies the use of alkyd resins in a semi-gloss enamel, while Federal Specification TT-E-489 calls for the use of alkyds in some thirty different colors for high gloss.

Where alkyds are used in white or light-tint enamels, the soya or dehydrated castor type are generally preferred because of their pale color and better color retention over prolonged periods. The use of these two types in baking enamels is also desirable if the film is to exhibit only a mini-

mum of non-yellowing. However, for extreme non-yellowing in white baking enamels the use of coconut oil alkyds (non-drying type) is preferred. The latter must be modified with a thermosetting resin such as urea-formaldehyde or melamine and heat-cured at high temperatures. The time and temperature varies with the amount and type of thermosetting resin present. Thirty minutes at 300 F, forty-five minutes at 275 F, or one hour at 250 F are general baking schedules.

Styrenated Alkyd Resins

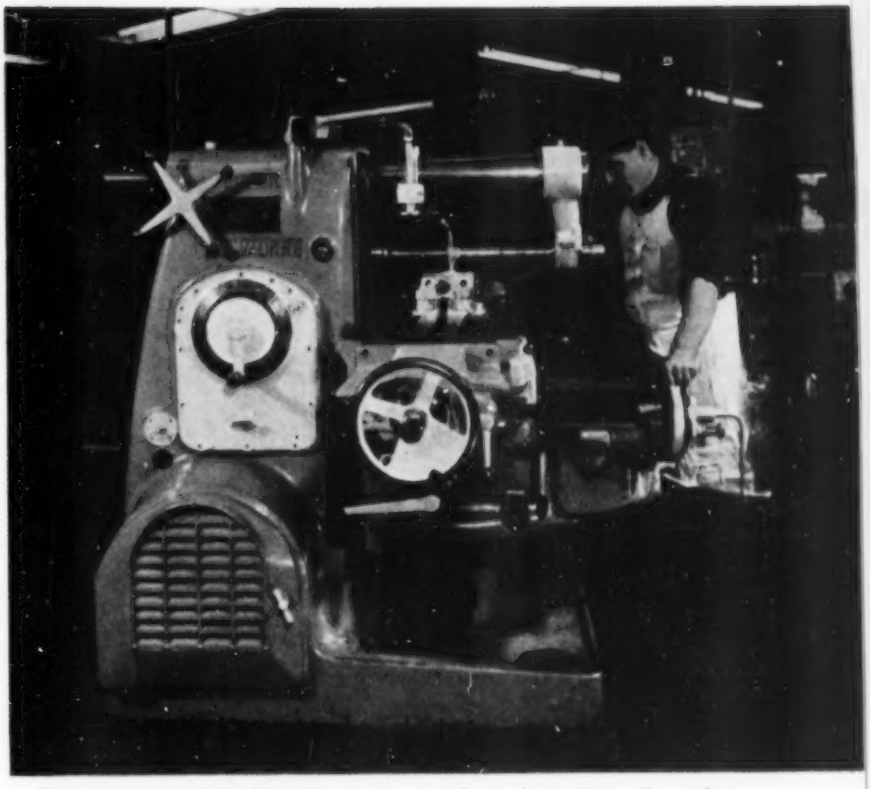
In the last three or four years a new modification of the alkyd resin was developed [1, 2, 3]. It was found that by chemical addition of styrene (a high polymer plastic), alkyd resins can be made to approximate the drying properties of cellulosic lacquers, still maintaining the normal properties of alkyd resins just cited.

Cellulosic lacquers have the unique property of drying by evaporation of solvent, while a paint or enamel dries by oxidation and polymerization after the volatile matter has left the film. In the latter, the drying-to-touch is effected anywhere from a few hours to a full day and metallic driers are required to catalyze the reaction. Styrenated alkyds, however, will dry within an hour and often without the addition of metallic driers.

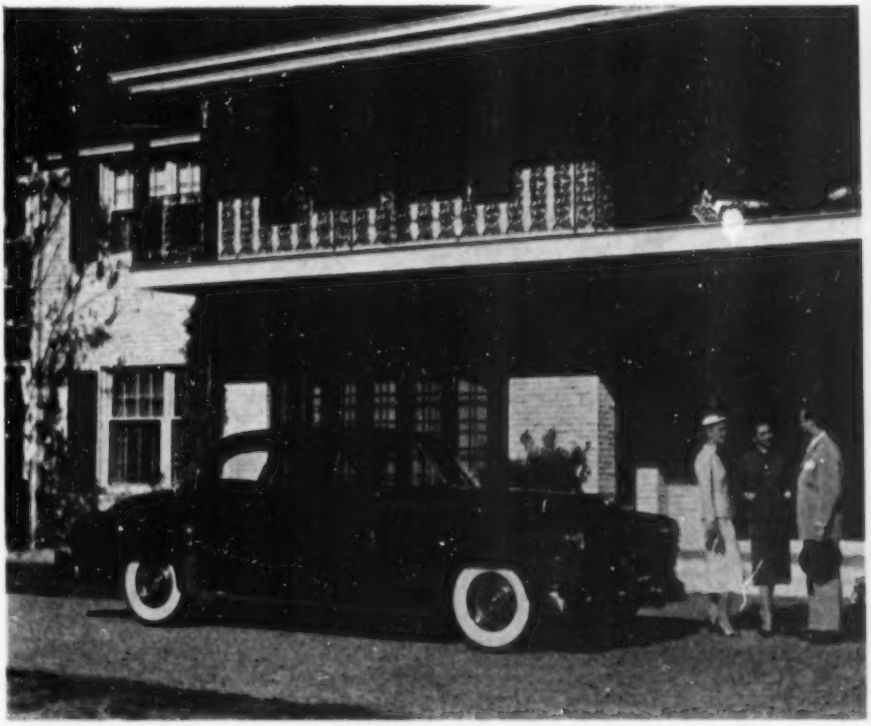
Enamels made with styrenated alkyds maintain the high non-volatile content at spraying viscosity of ordinary alkyd enamels. Therefore, from a "high build" point of view these coatings are preferred over the lower solid content cellulosic film formers. Several coats of lacquer are normally required to produce the film thickness of one coat of styrenated alkyd enamel. Therefore, from an economic standpoint the styrenated alkyd enamel would be desirable.

Styrenated alkyds are now specified for fast-drying ammunition enamels (e.g. Ordnance Specification MIL-E-10687).

A special feature of styrenated alkyd resins is their ability to produce a hammertone finish when pig-



The protection of machine shop equipment from the various oils, coolants and cleaning fluids necessitates the application of protective organic coatings to their surfaces. E. I. DuPont de Nemours & Co. and N. Y. Trade School



Automobiles illustrate the effectiveness of organic protective coatings in resisting the elements. These finishes are available in a wide variety of colors, including the polychromatic tones. Chrysler Corporation.

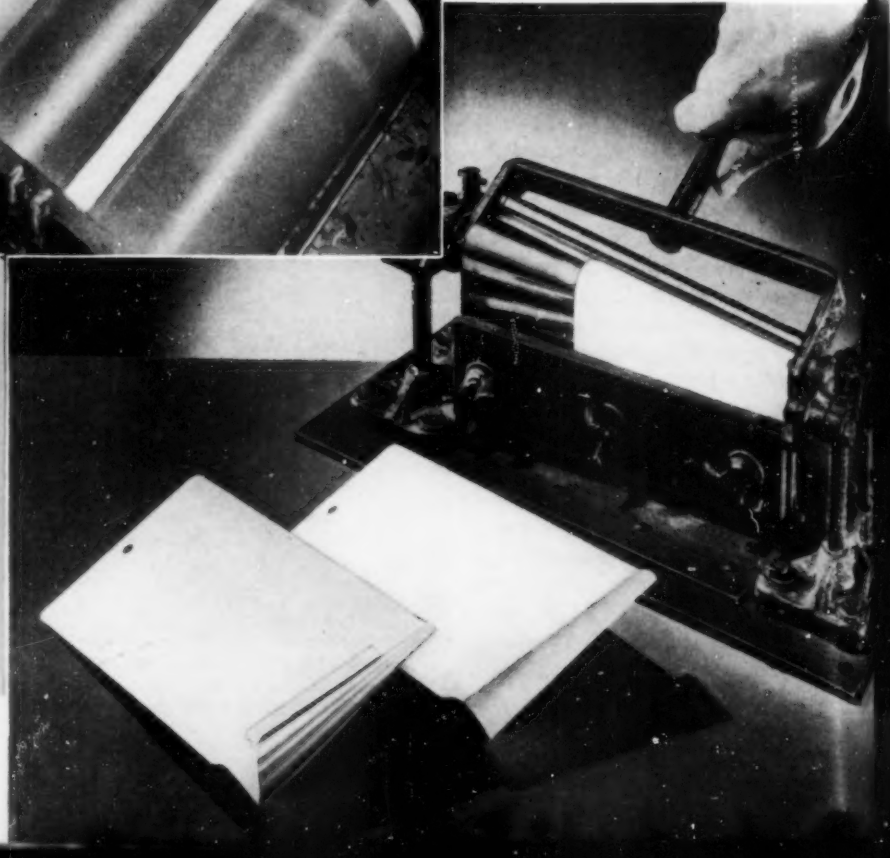
mented with aluminum powder or paste and pastel-colored pigments. When properly formulated, the enamel can produce in one application, polychromatic effects simulating a hammered aluminum pattern. Finishes of this type are used on industrial products such as automobile heaters, ditto machines, vacuum cleaners, and laboratory oven exteriors. Finishes can be applied by brush, spray or dipping.

Silicone-Alkyds

Another recent development in the protective coating field is the silicone-alkyds.[4,5] Silicone resembles carbon in its atomic structure and in chemical behavior. By substituting silicone atoms for atoms of carbon in the alkyd resin molecule, modified physical and chemical properties can be obtained. Silicone-alkyds demonstrate an improved hardness and high heat-resistance when compared to the ordinary alkyd resins.

Chemically these resins are produced by a reaction between an alkyd and a silicone-forming component. They are expected to find wide use in military applications because of heat-

Laboratory mixing of resin based paints is done on a small mill. Formulations are prepared and panels coated for testing purposes.
Goodyear Tire & Rubber Co.



A conical mandrel roll provides a comparison of adhesion and flexibility of paint films. Panels are bent around the cone which varies from ⅛ to 2 inches in radius.
Plaskon Division,
Libby-Owens-Ford Glass Co.

resistance and excellent resistance to weathering, humidity, chemicals, and salt spray. Space heaters, transformers, motors, chemical and refinery equipment, electric roasters, automotive exhaust pipes, sun lamps, refrigerators, stoves and stove hardware and steam radiators are some of the products for which silicone-alkyds would be suitable.

Air-drying silicone-alkyds are also available. These resins combine the superior weathering properties of silicone resins with the adhesion and flexibility of alkyds. It is claimed that weathered films have fifty to one hundred percent greater gloss retention on extended exposure than similar straight alkyds.

The greatest advantage of silicones is their high heat-resistance, but their superior hardness, abrasion resistance, adhesion and flexibility, and high resistance to solvents, acids, alkalis, gasoline and grease are properties not to be overlooked. Their high cost at present has prohibited their general use.

Silicone alkyd films have considerably higher heat resistance than most purely organic films. They maintain high gloss and stable color from 400 F to 500 F. One manufacturer states that no failure of films was observed at temperatures as high as 1500 Fahrenheit.

Silicone electrical insulating varnishes are used for impregnating coils, motors, transformers and other electrical equipment exposed to high ambient temperatures and to humid or corrosive atmospheres. It has been claimed that heat endurance, as indicated by ASTM flexing life tests conducted on aluminum panels at 250 C with one-eight inch rod, is about five hundred times as great as that of films formed by various high-grade organic varnishes.

Teflon

Another new member of the protective coating field is polytetrafluoroethylene or "Teflon", produced by DuPont.[6] "Teflon" finishes are not yet available in production quantities but limited amounts are obtainable for research purposes. "Teflon" products are available in low viscosity water dispersions.

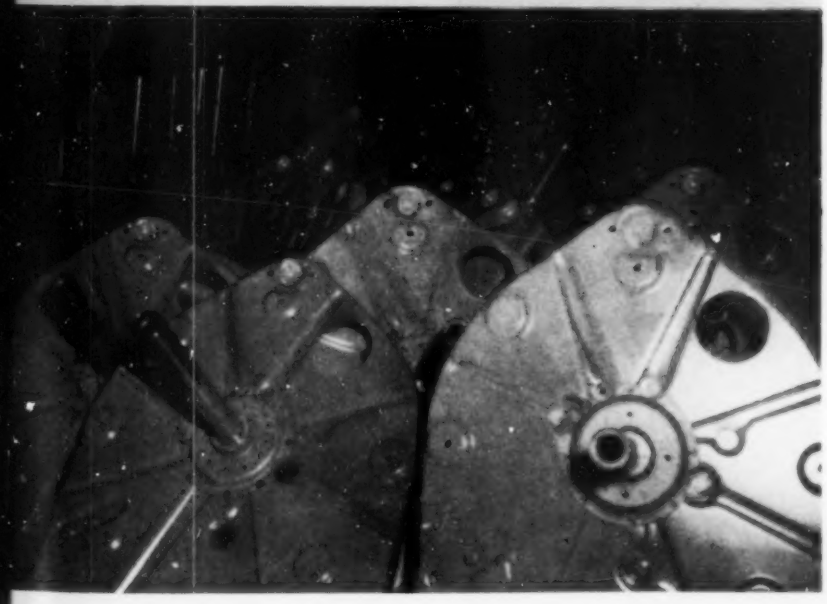
Two "Teflon" base primers are in use as protective coatings, one for steel and the other for aluminum. According to the manufacturer good adhesion is obtained on nickel and its alloys and sandblasted glass. Clear and pigmented white and red enamels are now being offered. These finishes are claimed to have good corrosion resistance and good heat stability. "Teflon" coatings can be applied by brush, spray, dip or flow coat, and can be baked at 750 F.

Epons

An entirely new class of condensation polymers is marketed under the name of "Epon."[7] When heat-cured this resin exhibits unusual flexibility, hardness and adhesion, and generally has good color and color retention. For surface coatings the "Epons" may be used alone or modified by reacting them with vegetable oils or their fatty acids.

When cooked into a varnish the "Epons" can be air-dried and therefore find use for floor varnishes and trade-sales items. The unmodified resins, when cold-cut, can be combined with urea-formaldehyde, melamine-formaldehyde and phenolic resins, all of which must be heat-cured. The heat-cured pigmented films are suitable for metal decorating, appliance finishes, farm implements and industrial primers. Clear films can be used for can and drum linings. The excellent chemical resistance of "Epons" makes them suitable for dairy, brewery, paper and laundry equipment. Because of their heat-resistant property, they can also be used in wire enamels.

Base plates for washing machine chassis are protected by Epon resin surface coatings against abrasion and soap solution corrosion. Shell Chemical Corporation.

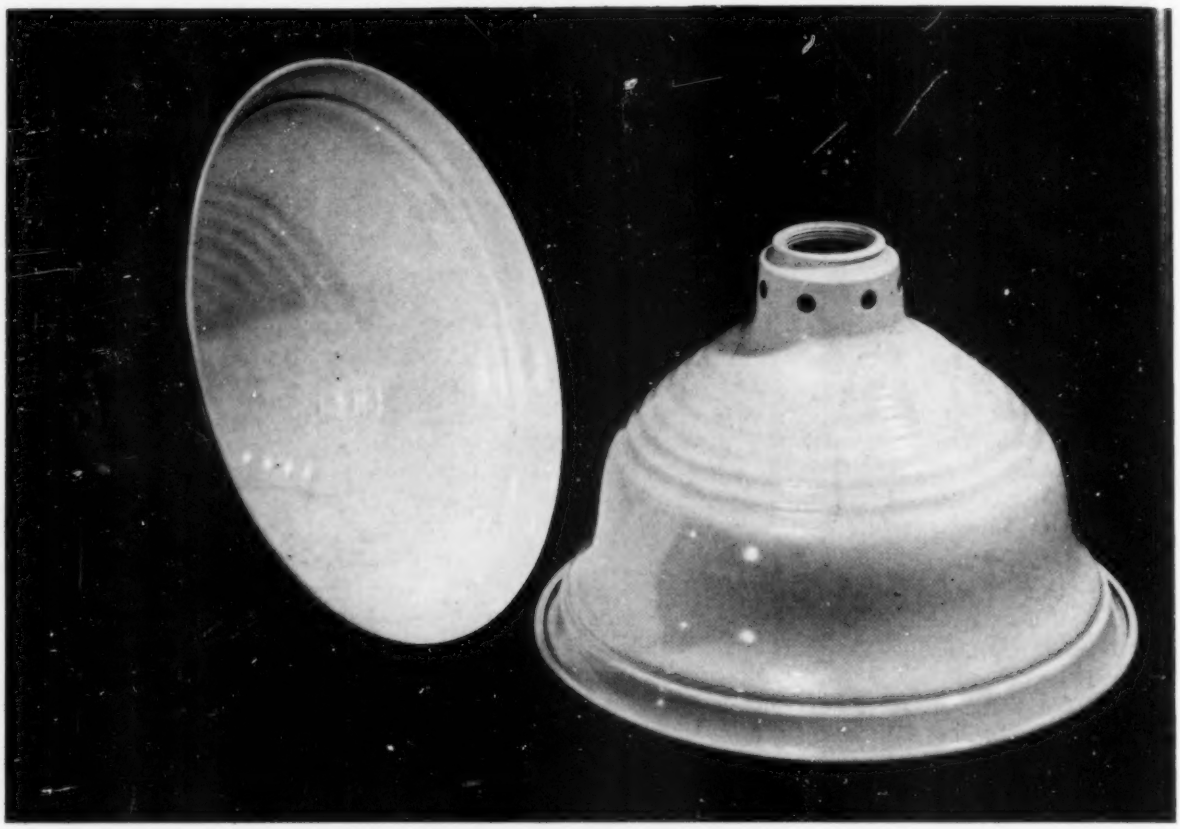


Acrylics

The acrylic resins are known as "Lucite" and "Plexiglass." Possibly one of the greatest potential fields in protective-coating technology lies in the use of acrylic polymers.[8]

Although the acrylic resins have been available in commercial quantities for several years, their use has been limited to relatively low-volume specialty applications because of cost. However, significant progress has been made in bringing these resins into relatively lower price levels, with the result that their applications have been greatly extended.

These resins are thermoplastic in



The exceptional heat resistance of the silicone alkyd resin based enamels is used to advantage for coating radiator covers, below, and lamp reflectors, above. Heater housings are also coated successfully. Plaskon Division, Libby-Owens-Ford Glass Co.

nature and films are formed from their solutions by solvent evaporation. They are available in organic solvents or water dispersions. They are permanently soluble in organic solvents and will re-soften at high temperatures. By baking the films at moderately high temperatures, good adhesion, high gloss and hardness are obtained.

The acrylics are charactertized by the following properties:

(1) Water-white in color, with perfect transparency and resistance to discoloration, even at high temperatures.

(2) Good resistance to water, alcohol, acids and alkalis.

(3) Good resistance, generally, to vegetable and mineral oils and greases.

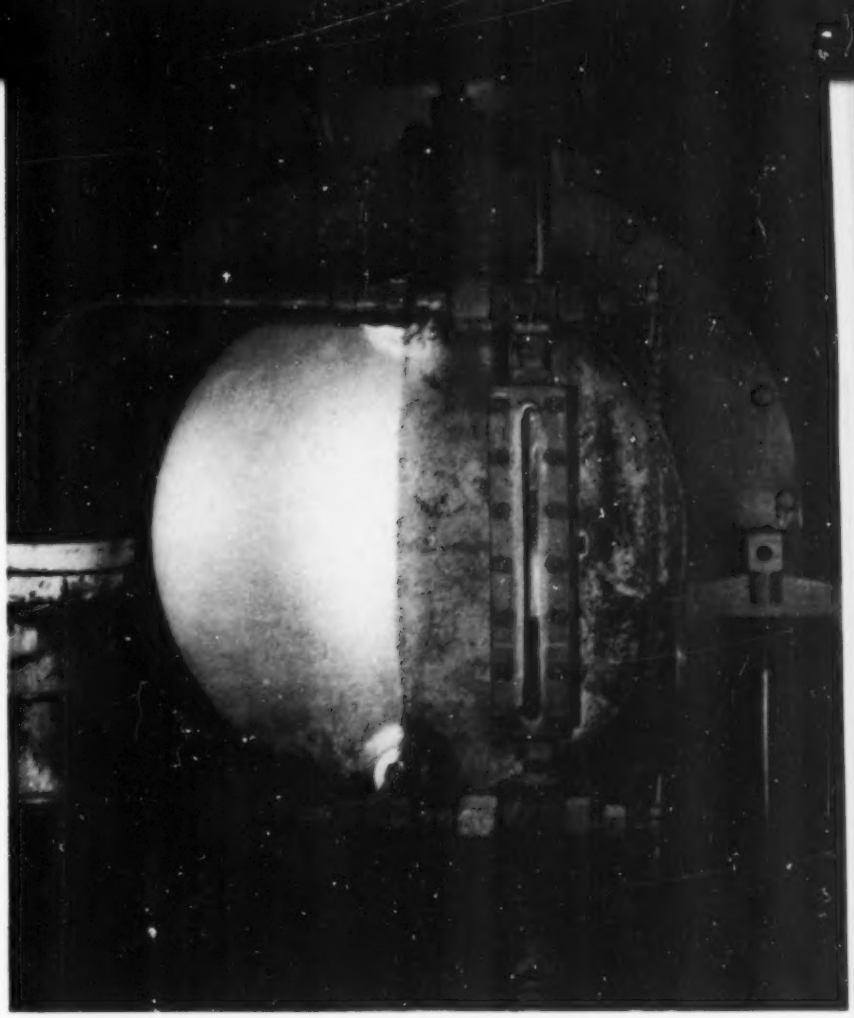
(4) Outstanding resistance to chemical fumes.

(5) Good electrical properties.

(6) Relatively high resistance to combustion.

(7) Good package stability.

(8) Outstanding flexibility and



A highly industrial application of silicone-alkyd resins is in the coating of boilers and boiler pipes and connections. The left half of the above boiler has been coated with a silicone alkyd finish.

Plaskon Division, Libby-Owens-Ford Glass Co.

adhesion to most metallic substrates.

Industrially, the acrylic resins are useful as clear coatings for metal, in fume-proof and heat-resistant enamels, as adhesives and cements, as vehicles for luminescent pigments, in high grade artificial leather, in electrical coatings, in shatter-resistant glass coatings, and in white enamels for boiler dials. Generally, they are applied by spray or dip application.

Urea-Formaldehyde-Melamine-Alkyd Combinations

The properties and applications of alkyd resins were previously described. The combination of alkyd resins with urea-formaldehyde or melamine thermosetting-type resins is not a novel idea in the industrial coating field. The more common uses of these combinations can best be illustrated by the high gloss, high depth, extremely hard porcelain-type finish on the modern refrigerator, washing machine or gasoline pump.

The ureas and melamines are thermo-setting type resins, convertible by heat to practically colorless, non-yellowing, extremely hard, brittle films, having excellent resistance to solvents and many other chemicals. The baked films alone lack adhesion and are generally brittle. They are usually formulated with more elastic film-formers such as the alkyds which impart excellent adhesion, gloss and abrasion resistance.

Ranking high among new developments in this group are improved urea formaldehyde and triazine formaldehyde resins [11] for use in baking finishes applied to automobiles, farm equipment and home appliances. Outstanding developments have been made in soap and alkali resistance with greater compatibility and gloss than have been obtained with nitrogen resins.[12]

Vinyl Resin Coatings

Vinyl resins [13, 14] for the surface-coating field are thermoplastic, neutral, non-oxidizing and non-polymerizing in nature. They deposit films by evaporation of solvent similar to the cellulosic film-formers.

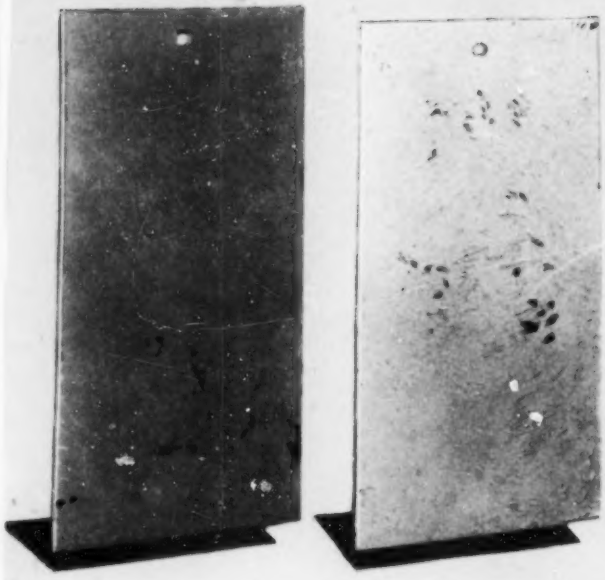
Because of complete absence of taste, odor or toxicity, one of the largest uses for vinyl resins is found in the coating of food and beer cans, linings for bottle caps, closures and coatings for food wrappers.

Toughness, adhesion and flexibility of vinyls permit them to be used as coatings on flat metal sheets subjected to extreme drawing, stamping or forming.

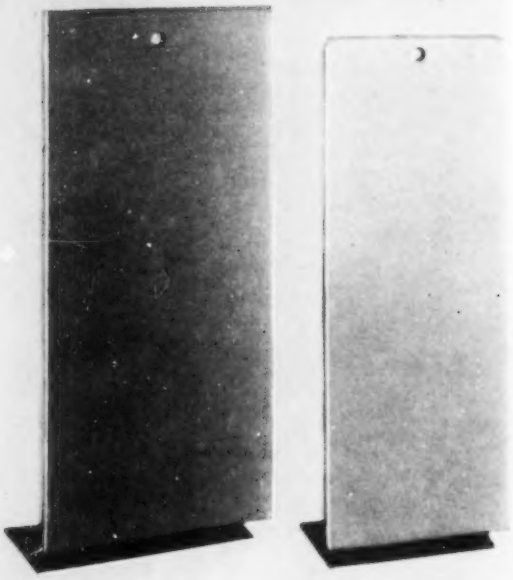
Because of their exceptional resistance to most corrosive chemicals, vinyl resins are being used in chemical containers, for stop-off lacquers in electroplating, for protection of processing vats, as coatings to protect equipment from corrosive atmospheres, etc. Their alkali resistance enables these finishes to be used on masonry, asbestos board and cement board. Their general resistance to oils, greases and moisture permits their use on table and bar tops, refrigerators parts and cosmetic containers. Their excellent weathering properties make them highly desirable for use on metal signs, garden furniture and other equipment exposed to the elements.

Vinyl resins have been successfully applied by means of solution techniques, as dispersions in organic media or in water. They may be pigmented or plasticized as desired and applied by spraying, dipping or roller coating. For certain applications a technique has been developed for applying vinyl resins in the form of dispersions known as organosols and plastisols.[15] Those resins prepared with volatile thinners are called "organosols"; those containing no volatiles and dispersed in plasticizers only, are called "plastisols."

Organosols are used on cloth, paper, metal foils and dipped goods; plastisols are used for the heavy



The heat resistance of silicone-alkyd resin enamels is indicated by the above panels. The melamine-alkyd resin, left, failed when exposed to 350 F for 50 hrs.



The silicone-alkyd films, right, withstood 350 F for 500 hr. and 450 F for 300 hr. without film breakdown.
Plaskon Division, Libby-Owens-Ford Glass Co.

flexible coatings of tank linings, plating racks and other items.

Coating problems involving storage and shipping may be solved by strippable films based on vinyl resins.[16] Two types of coatings are available for this purpose. One is a tightly adhering film which is capable of being stripped from the surface. This coating offers protection against moisture, weather and corrosion. It is well suited for gun turrets on battleships, gun mounts, fighter planes, etc. An overall package for encasing large shaped pieces of equipment begins with a framework of masking tape built around the object to be sealed. A vinyl webbing agent is sprayed around this tape in cobweb-like form to fashion a base for the strippable coating. The coated object then becomes completely enclosed in this "liquid plastic" and is preserved against moisture and corrosive atmospheres. The object, when ready for use, can be very easily uncoated by tearing into the film and stripping it off.

A fairly recent outstanding development based on vinyls is an anticorrosive wash primer or undercoat for use on metal,[17] particularly for naval vessels. The composition of the primer consists of vinyl butyral resin, zinc chromate and phosphoric acid. The wash primer adheres to metals such as steel, brass, aluminum, cadmium and galvanized surfaces. Because of its outstanding properties as a primer, the government issued a specification, MIL-P-15328, establishing this coating as a standard material for ships. Aside from the properties just mentioned, an outstanding advantage of this material is its short drying time.

In the last few years, a newer type of vinyl resin has become commercially available that exhibits broader versatility as a general coating. This resin, VAGH,[18] a product of the Bakelite Company, shows wide compatibility with many classes of film-formers, especially alkyd resins, making possible many new types of fortified coatings. Coatings made with this material adhere tenaciously to the vinyl butyral wash primer. The government has recently issued several paint specifications based on the use of this resin.

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Fundamental Transverse Frequencies Of Tapered Cantilever Bars

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Assumed mode shapes used in the calculation of the fundamental frequencies of cantilever bars are applied to bars of constant circular cross-section and to conical bars. Inherent errors are compared and a more accurate mode shape is derived.

WHEN A DESIGN PROBLEM calls for the determination of the fundamental frequency of transverse vibration of a nonuniform bar, the Rayleigh energy method offers perhaps the simplest approximate approach to the problem. In this method, a guess is made regarding the fundamental mode shape of the vibrating bar. The strain energy (potential energy) of the bar at maximum strain is then equated to the kinetic energy of the bar in going through equilibrium position. The kinetic energy expression contains the unknown frequency, which may be solved for from the resulting equality.

Where

- E = modulus of elasticity of the bar material
- γ = weight per unit volume
- g = acceleration of gravity
- x = distance along the bar from the built-in end
- $y = f_1(x)$, a function representing the assumed mode shape
- $A = f_2(x)$, a function representing the cross sectional area of the bar
- $I = f_3(x)$, a function representing the moment of inertia of the cross section about a principal axis.

then the natural frequency for transverse vibration in this mode (See Timoshenko, "Vibration Problems in Engineering," 2nd Edition, p 337) is given by

$$\omega^2 = \frac{Eg}{\gamma} \frac{\int_o^L I\,(d^2y/dx^2)^2 dx}{\int_o^L Ay^2\,dx} \qquad (1)$$

Books that describe the Rayleigh method in connection with vibration problems usually state that the fundamental frequency may be determined with good accuracy by assuming any reasonable deflection curve (See Thomson, "Mechanical Vibrations", p 31). Examples are then shown in which the approximate frequencies so calculated are within 5 percent or better of known exact values for the selected systems considered. These frequencies are always higher than the true frequencies. If various assumptions are made as to mode shape and the frequencies calculated, the lowest of the calculated frequencies is always the most accurate.

What constitutes a "reasonable" approximation to the mode shape, unfortunately, is not always clear. Usually an attempt is made to make the end conditions for the assumed mode shape agree with the true end conditions for the bar. Thus, for a cantilever bar the true end conditions consists of zero deflection and zero slope at the built-in end, and zero moment and zero shear at the free end. Presumably, an assumed mode shape for a vibrating cantilever should satisfy these conditions at its ends. In common beam theory for the bar of Fig. 1, where I may be variable with x but E is assumed to be constant, these conditions are expressed as

$$\text{At } x = 0,\ y = 0,\ dy/dx = 0 \qquad (2)$$
$$\text{At } x = L,$$
$$EI\frac{d^2y}{dx^2} = 0,\ E\frac{d}{dx}\left(I\frac{d^2y}{dx^2}\right) = 0 \qquad (3)$$

To see how they satisfy the conditions (2) and (3), some of the modes usually assumed for cantilevers will now be studied.

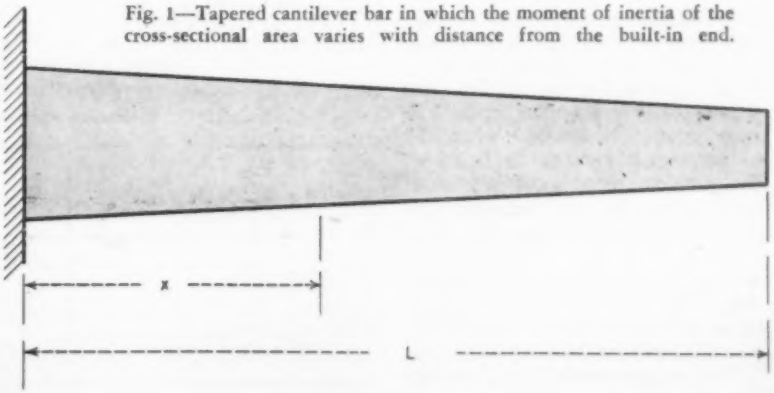
For a uniform cantilever the quarter-cosine wave is often found in literature (See Den Hartog, "Mechanical Vibrations", 3rd Edition, p 191). The equation for this shape is

$$y = 1 - \cos(\pi x/2L) \qquad (4)$$

The end conditions for a uniform cantilever bar bent to this shape are

$$\text{At } x = 0,\ y = 0,\ dy/dx = 0 \qquad (5)$$
$$\text{At } x = L,$$
$$EI(d^2y/dx^2) = 0,$$
$$Ed\,[I(d^2y/dx^2)]/dx = -(\pi/2L)^3 EI \qquad (6)$$

Fig. 1—Tapered cantilever bar in which the moment of inertia of the cross-sectional area varies with distance from the built-in end.



It is evident that the shear condition at the free end is not fulfilled, although the other conditions are. As it is, the approximate frequency based on the quarter-cosine assumed made shape is within 4 percent of the exact theoretical value. This approximation represents good agreement and is computed with little effort.

Another assumed mode shape frequently used is the static deflection curve of the bar under a concentrated load applied at its end. The equation for this case is

$$y = 3\,(x/L)^2 - (x/L)^3 \tag{7}$$

The end conditions for a uniform cantilever bent to this shape are

$$\text{At } x = 0,\ y = 0,\ dy/dx = 0 \tag{8}$$

$$\text{At } x = L,\quad EI(d^2y/dx^2) = 0,\quad Ed\,[I(d^2y/dx^2)]/dx = -\,EI\,(6/L^3) \tag{9}$$

Here, again, the condition of zero shear at the free end is not fulfilled. This shape gives a frequency within 1½ percent of the exact value. The increase in accuracy of the second assumption over the first occurs in spite of the greater deviation in the end condition for shear. The reason lies in the better approximation occurring over the whole bar.

A third, and extremely simple, mode shape is the parabola given by

$$y = (x/L)^2 \tag{10}$$

The end conditions for a uniform cantilever bent to this shape are

$$\text{At } x = 0,\ y = 0,\ dy/dx = 0 \tag{11}$$

$$\text{At } x = L,\quad EI(d^2y/dx^2) = EI\,(2/L^2),\quad Ed\,[I\,(d^2y/dx^2)]/dx = 0 \tag{12}$$

In this case the second derivative has a constant value different from zero over the entire length of the beam. This condition corresponds to that of a cantilever loaded by a couple at its free end. This shape is very bad for accuracy, giving a frequency which is 27 percent too high.

Bearing in mind the variation in frequency that has resulted in the foregoing cases from various assumptions as to mode shape, it is interesting to use the same expressions for a straight-tapered bar of circular cross section fixed at its thick end. The greatest taper is attained when the bar becomes pointed at its free end. The problem then becomes one of determining the fundamental frequency of a right circular cone fixed at the base and free at the tip. An exact solution for this case is available (See Timoshenko, p 380), so that the degree of error in using the approximate mode shapes may be determined.

For a straight-tapered bar of circular cross section pointed at its free end and fixed at its thick end where

r_o = radius of the cone base
$a = r_o/L$ = slope of cone surface
r = radius of cross section at distance x from fixed end
A = area of cross section of radius r
I = moment of inertia of cross section of area A

$$r = a\,(L - x) \tag{13}$$

$$A = \pi r^2 = \pi a^2 (L - x)^2 \tag{14}$$

$$I = \pi r^4/4 = (\pi a^4/4)\,(L - x)^4 \tag{15}$$

Assuming the quarter-cosine shape for the bar, the displacement and slope conditions at the fixed end and the moment condition at the free end are satisfied as in the case of the uniform bar. Because I goes to zero at the free end, the shear condition there is also satisfied, in contrast to the case of the uniform bar. Upon substituting the values of I and A and the quarter-cosine function into the frequency Eq (1), and performing the integrations called for, the frequency is found to be

$$\omega = 4.72\ \sqrt{E\,g/\gamma}\,(r_o/L^2) \tag{16}$$

The exact value is

$$\omega = 4.359\ \sqrt{E\,g/\gamma}\,(r_o/L^2) \tag{17}$$

A comparison of Eqs (16) and (17) shows that an error of 8 percent is involved.

If the deflection curve of Eq (7) is used for the mode shape, all end conditions are again satisfied exactly, the shear at the free end going to zero because I goes to zero. Making use of Eq (1), the frequency is found to be

$$\omega = 5.07\ \sqrt{Eg/\gamma}\,(r_o/L^2) \tag{18}$$

which is 16 percent too high.

Finally, making use of the parabola, Eq (10), it will be found that all of the end conditions are also satisfied for the conical bar. The moment goes to zero at the free end because I goes to zero there. Under these conditions, the frequency for the cone is found to be

$$\omega = 4.58\ \sqrt{Eg/\gamma}\,(r_o/L^2) \tag{19}$$

which is only 5 percent high.

To summarize the results for the straight beam and the cone, the errors in the fundamental frequencies are tabulated in the first three rows of Table I against the assumed mode shapes. The fourth and fifth rows of Table I will be explained in later paragraphs.

The data given in Table I point out that if a single approximate mode shape were to be used for all straight tapers between that of the uniform bar and a cone, the quarter-cosine curve would provide the best overall results. The parabola is exceptionally poor in this respect, although it does well for the cone alone.

Referring to the second of the three shapes studied, it is evident that it consists of a mixture of a parabola and a cubic in a three to one proportion. It is possible that by a more judicious choice of this proportion better accuracy could be attained for the cylinder and for the cone. It is desirable, therefore, to express this mode shape in the form:

$$y = n\,(x/L)^2 - (x/L)^3 \tag{20}$$

and to adjust n so that a minimum frequency results in each case.

Applying this method first to the cylinder, the integrations in the numerator and denominator of Eq (1) are found in terms of n as follows:

$$\int_o^L I\left(\frac{d^2y}{dx^2}\right)^2 dx = \frac{\pi r_o^4}{L^3}\,(n^2 - 3n + 3) \tag{21}$$

$$\int_o^L Ay^2 dx = \pi r_o^2 L\left(\frac{n^2}{5} - \frac{n}{3} + \frac{1}{7}\right) \tag{22}$$

From Eq (1), the frequency is obtained in terms of n as follows:

$$\omega^2 = \left(\frac{Eg}{\gamma}\,\frac{r_o^2}{L^4}\right) \times \left[\frac{n^2 - 3n + 3}{(n^2/5) - (n/3) + (1/7)}\right] \tag{23}$$

The value of n that makes ω^2 a mini-

Table I—Errors in Fundamental Frequency Calculations for Cantilever Bar

Assumed Mode Shape	Percent Error	
	Uniform Bar	Conical Bar
$1 - \cos(\pi x/2L)$	4	8
$3\,(x/L)^2 - (x/L)^3$	1.5	16
$(x/L)^3$	27	5
$2.606\,(x/L)^2 - (x/L)^3$	0.5	.....
$-0.7391\,(x/L)^2 - (x/L)^3$	.....	0.2

mum is obtained from the equation:

$$\frac{d\omega^2}{dn} = 0 = 7n^2 - 24n + 15 \qquad (24)$$

The roots of Eq (24) are

$$n = 0.822143, \text{ and } 2.606429 \qquad (25)$$

The first value of n leads to a very high frequency, corresponding roughly to a second mode of vibration. The second value of n, which is fairly close to the 3 originally used, leads to the frequency

$$\omega = 1.7663 \sqrt{Eg/\gamma}\,(r_o/L^2) \qquad (26)$$

which is within ½ percent of the exact value.

When the method is applied to the conical bar, the following relations are obtained

$$\int_o^L I \left(\frac{d^2y}{dx^2}\right)^2 dx = \frac{\pi a^4 L}{5}\left(n^2 - n + \frac{3}{7}\right) \qquad (27)$$

$$\int_o^L Ay^2 dx = \pi a^2 L^3 \left(\frac{n^2}{105} - \frac{n}{84} + \frac{1}{252}\right) \qquad (28)$$

The optimum value of n is obtained from

$$\frac{d\omega^2}{dn} = 0 = n^2 + \frac{98}{1029}n - \frac{1470}{3087} \qquad (29)$$

The roots of Equation (29) are

$$n = 0.643905, \text{ and } -0.739145 \qquad (30)$$

The positive value of n leads to a rough approximation of the second mode frequency. The negative value leads to the frequency:

$$\omega = 4.3675 \sqrt{Eg/\gamma}\,(r_o/L^2) \qquad (31)$$

which is within 2/10 percent of the exact value.

These results are given in the fourth and fifth rows of Table I. They show that highly accurate results may be attained by assuming a mixed parabola and cubic for the mode shape of a nonuniform cantilever, and adjusting their relative proportions to minimize the resulting frequency.

Metal Sandwich Decorates Plastic Parts

FRONT SURFACE METALLIZATION of plastic products produces a decorative coating that is abrasive resistant and non-tarnishing, and its application is limited only by the ingenuity of the designer. The coating consists of a thin film of evaporated metal sandwiched between layers of lacquer.

In applying such coatings, pretreatment of the product consists of cleaning all surfaces and removing all volatiles. Washing with a suitable detergent and rinsing in clear water is usually adequate. But special cleaning precautions should be taken to remove mold lubricants since these materials produce dull or black spots on the final metallized product.

There are three steps in the actual processing: coating the product with lacquer and baking to provide a suitable base or undercoat upon which to evaporate the metal; high vacuum evaporation of the metal to produce the metallic film; and coating with lacquer and baking to protect the film against abrasion, corrosion and general service abuse.

The lacquer undercoat fills in and seals the microscopic pores of the surface. This eliminates surface irregularities that would be reproduced by the thin metal film and decreases the length of time required to pump down the vacuum chamber since these pores provide gas traps which outgas during the vacuum coating. In addition it prevents surface occluded gases from interfering with adhesion of the metal.

Requirement specifications for this undercoat include: 1) adhesion to the object being metallized. This depends on the object being coated, since, for example, some lacquers adhere well to cellulose acetate but not to polystyrene. 2) Volatile content. Residual volatility after the lacquer has set is important because it may cause imperfections in the metal coating and prevent satisfactory adhesion of the topcoats. It is usually caused by plasticizers in the lacquer that with aging tend to migrate in relatively high concentrations to the surface of the film. 3) Surface characteristics. Specific surface effects ranging from a high gloss to wrinkle finishes are dependent on the composition of the undercoat. 4) Compatability to topcoating. Both lacquer coatings must be selected so that topcoat will adhere to the base, and the undercoat will withstand immersion procedures as well as exhibit stability to reaction with hot volatiles during topcoat drying.

The high vacuum metallization is basically an evaporation and condensation process. A metal, usually aluminum, is brought to its boiling point inside a chamber which is evacuated to below one millionth of an atmosphere pressure. The metal boils off in vapor form and travels in straight lines from the point of evaporation until it hits some object on which it can condense. When enough vapor condenses to form a continuous film several millionths of an inch thick, a metallic surface is visible.

This coating possesses all the normal appearances of metal and has its electrical properties. In production, the thickness of the coating is determined by the time of evaporation.

It is essential that the pressure in the evaporating chamber be carefully controlled during metallizing. If the pressure rises above a minimum of one-millionth of an atmosphere, the quality of the coating will be impaired by the formation of dark oxidized surfaces.

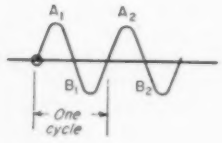
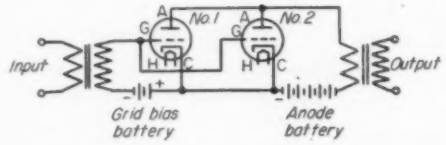
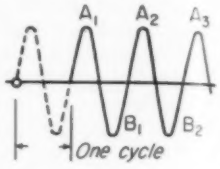
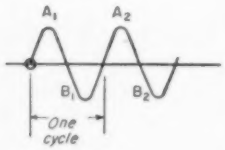
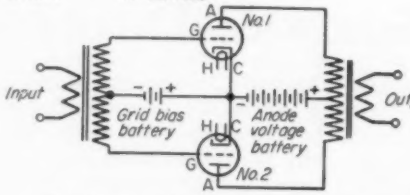
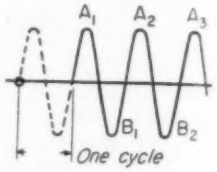
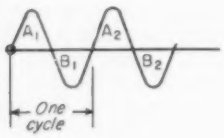
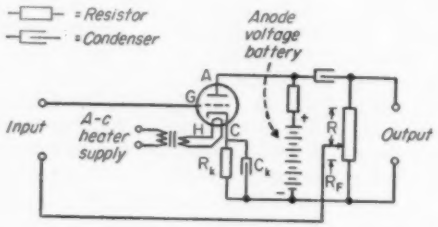
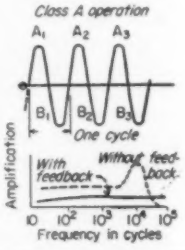
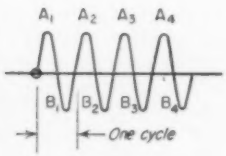
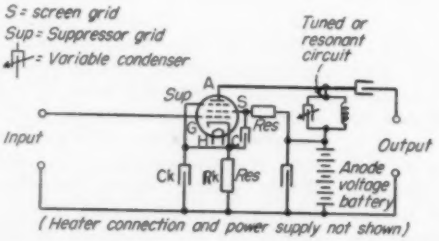
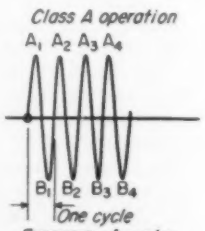
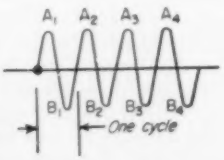
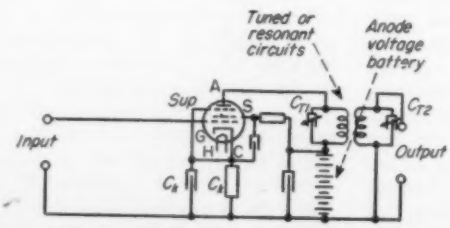
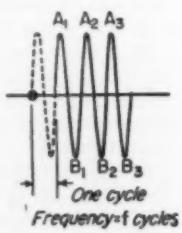
Finally, the vacuum metallized product requires a clear white transparent overcoat in order to protect the metal deposition against service abuse and to provide the medium for introducing color effects. While the same requirements for the undercoat are applicable to the overcoat, the latter does not have such stringent requirements for residual volatility. This is not important in the overcoat unless the volatiles affect the base and distort the metal film. However, the lacquer must be able to withstand all anticipated service abuse such as abrasion, humidity, solvent attack, impact, and ultra-violet radiation.

Aluminum, the usual metal deposited, is highly reflective and by dye-tinting the topcoat, it is possible to produce metallic appearances including most of the colors of the visual spectrum.

According to Distillation Products Industries, makers of production metallizing equipment, this process will eventually replace other methods of applying a metal finish to plastics. DPI offers these reasons to substantiate their belief:

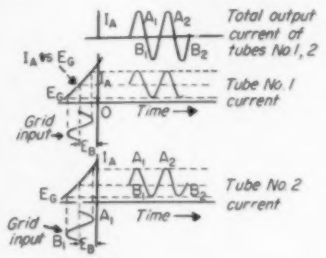
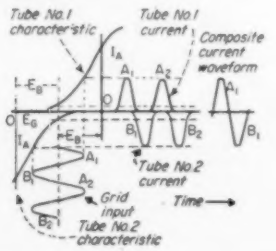
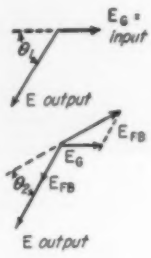
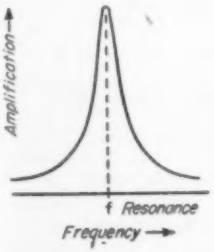
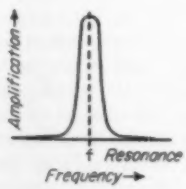
1. In most instances, the use of vacuum metallization equipment will permit lower per unit processing costs.
2. Special surface finishes, such as metallic colors, and a brushed, hammered or wrinkled effect can be produced without additional operations.
3. Metal shortages have little effect on the process because only minimal amounts of metal are used.
4. Variations of well known handling techniques may be used—such as methods of applying lacquer undercoat and overcoat by dipping and spraying.
5. Cheaper base materials, such as regrinds, can be used without debasing the quality of the final products.

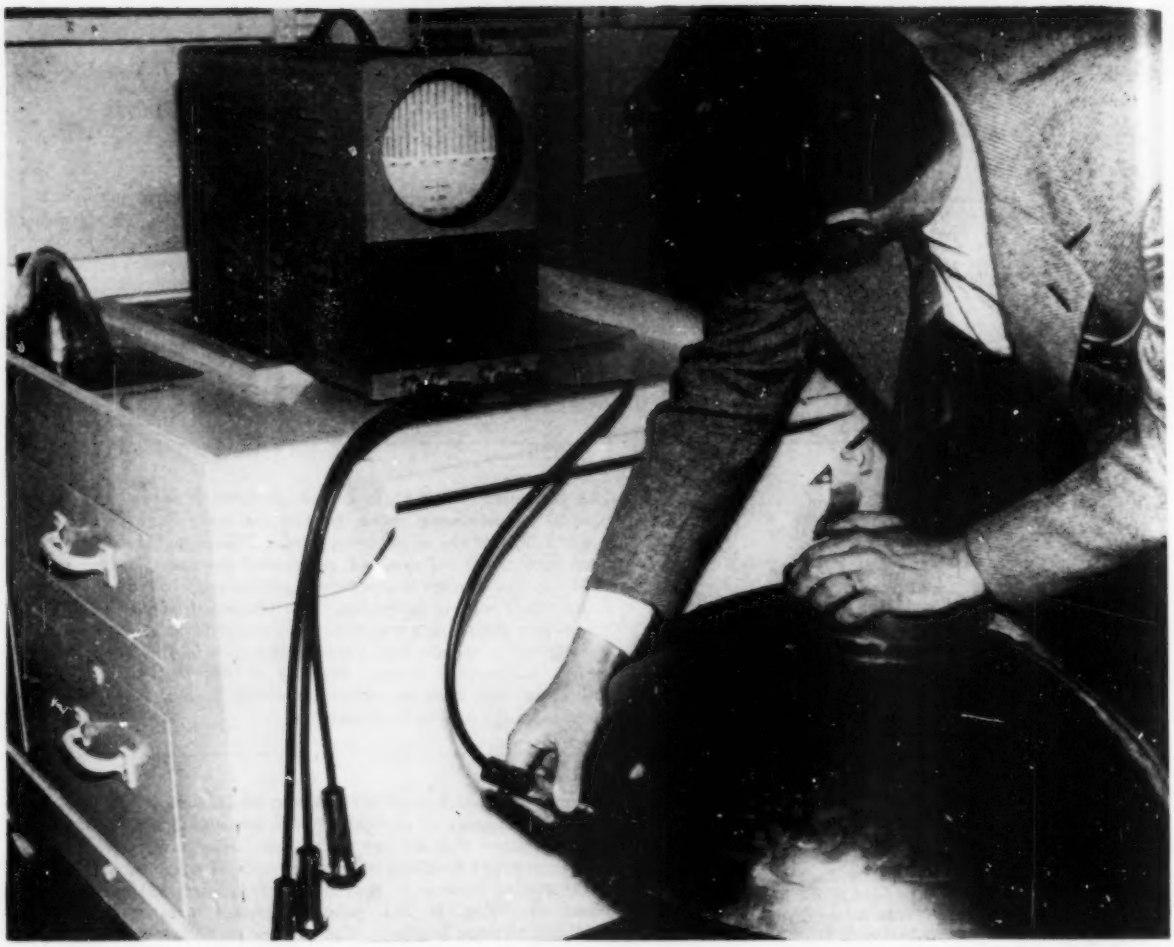
Power and Voltage Amplifiers

Type	Input Voltage	Circuit Sketch	Output Voltage
Parallel Tube Power Amplifier (Triode)	 f = Frequency (A-C sine wave)	E_B = Grid bias voltage; E_A = Anode battery voltage; I_A = Anode current; E_G = Grid input voltage  (Grid bias suitable for class A, AB, B or C operation)	Class A operation  Frequency = f cycles
Push-Pull Power Amplifier (Triode)	 f = Frequency (A-C sine wave)	A = Anode; H = Heater; G = Grid; C = Cathode  (Heater connection and power supply not shown)	Class B operation  Frequency = f cycles
Negative Feedback Voltage Amplifier (Triode)	 f = Frequency (A-C sine wave)	= Resistor; = Condenser 	Class A operation 
Single-Tuned Radio-Frequency Voltage or Power Amplifier (Pentode)	 f = Frequency (A-C sine wave)	S = screen grid; Sup = Suppressor grid; = Variable condenser  (Heater connection and power supply not shown)	Class A operation  Frequency = f cycles
Double-Tuned Radio-Frequency Voltage Amplifier (Pentode)	 f = Frequency (A-C sine wave)	 (Heater connection and power supply not shown)	 Frequency = f cycles

R. B. IMMEL
Westinghouse Electric Corporation

Fundamental Electronic Circuits

Operation	Remarks
	Two or more tubes may be connected in parallel to provide a higher power output than is possible with one tube. The power output is proportional to the number of tubes employed in the circuit. The grid control potential required is the same as for one tube. If the tubes are operated for Class *C* amplification, or if power is consumed in the grid circuit, the grid power required is proportional to the number of tubes in the circuit. In this particular circuit, the d-c anode current saturates the transformer. The voltage phase shift can be reduced by reversing the polarity of the transformer output winding.
	The push-pull circuit for a power amplifier is superior to the parallel circuit shown above, because the wave form distortion is much less for the same power output. The term "push-pull" is used because the voltages and currents of the two tubes are out of phase. The current in one tube is increasing while the current in the other tube is decreasing. This characteristic can be illustrated very clearly in a graphical analysis for Class *AB* amplifier. This circuit is widely used because distortion is less (even harmonics cancel each other); there is no d-c transformer iron saturation (d-c currents cancel each other); and little or no filtering of the output is required.
 Victor diagram of amplifier with inductive load and without feedback. The angle θ is the phase distortion. With a feedback voltage E_{fb} added to the grid voltage E_g, the phase distortion θ_2 is reduced. The feedback factor is: $$B = \frac{R_F}{R_F + R}$$	A negative feedback amplifier is one in which some of the amplified output energy is introduced into the input grid circuit in such a manner that the net grid input voltage is reduced. Although negative feedback reduces the gain or amplification, it is advantageous because it reduces the frequency, harmonic and phase distortion. It also provides greater stability than an amplifier without feedback. The performance characteristics are not as sensitive to changes in individual tubes or in the applied voltage. The amplification vs frequency characteristic is almost constant for a wide frequency range. Positive feedback is unstable and may cause the amplifier to oscillate.
 This type of amplifier operates similarly to those previously described except that it can be tuned to be more responsive to one particular frequency or frequency range. The value of inductance and capacitance determine the resonant frequency.	Five-element tubes are usually used in high frequency or radio-frequency amplifiers because the inter-electrode capacitances are considerably lower than those of a three-element tube. This particular type of amplifier circuit is seldom used as a voltage amplifier, since its characteristics are inferior to those of the double-tuned or transformer coupled types. Because of the inductance coil limitations, it is seldom possible to obtain more than 10 percent of the tube amplification factor. This circuit is frequently used for power amplification.
 Both the primary and secondary of the transformer of this circuit are tuned. The frequency of resonance or maximum amplification can be varied by changing the capacitance value of condensers C_{t1} and C_{t2}.	This type of circuit is widely used in broadcast receivers since it is responsive only to a certain frequency range. Also, as the cut-off characteristic is sharp and the maximum amplification range is broader and almost constant near the resonant frequency, it permits easy tuning or selection of the frequency to be amplified. A common application of this circuit is for intermediate frequency amplification in a superheterodyne radio receiver.



Nondestructive testing of materials for structural defects is best-known industrial use of ultrasonic energy. Echo reflection and resonance methods are effective in showing voids in solids and sensitive to changes in grain structure. *Magnaflux Corporation*

Putting ULTRASONICS *to Work*

Current practice tends to lump most all applications of vibratory energy under the term "ultrasonics". Industry is beginning to put this energy to work, at frequencies both in and above the sonic range, to locate flaws in metals, mix incompatible liquids, cut tough materials and clean precision machined parts.

BOYD WISE
DALE ENSMINGER
Battelle Memorial Institute

THOUGH THE TERM "ultrasonic" refers to all mechanical vibrations at frequencies higher than the upper limit of human bearing—about 16,000 cycles per second, this range does not include all of the important industrial applications of vibratory energy. Some of the applications are best carried out at audible frequencies as low as 60 vibrations per second; others, requiring the scattering of sound waves by minute particles or surface irregularities, are best generated at frequencies of about 20 million vibrations per second. Thus, there is no magic dividing line in the frequency spectrum above which useful results can be obtained, and below which they cannot.

Sound has several important characteristics. It is a wave motion, similar in many respects to light waves, and is propagated with different velocities in different materials—about 4,500 ft per sec in liquids and 15,000 ft per sec in metals. As sound is propagated through a material, the motion of the material's particles can be described by the amplitude, frequency, velocity and acceleration with which the particles move. Because of the elastic properties and the mass of the material in which

a sound wave exists, there is a definite amount of energy contained in and being transferred by the sound wave. The term "sound intensity" expresses the energy being transferred through a unit area in unit time by a sound wave.

Depending on the source, a sound wave can spread out, like rays from the sun, or be highly confined, like the beam from a searchlight. As with light, sound is transmitted well by some materials and blocked or rapidly decreased in intensity by others. It can be reflected by a sound mirror or refracted by a sound lens. All of the diffraction effects (such as those that make a pin-hole camera work) are obtainable with sound, and some sound waves can even be polarized. Unlike light, however, sound waves must have some physical material in which to exist because they cannot be propagated in a vacuum.

Many of the useful applications of sound waves can be thought of as depending on one of two sets of properties. The first set includes those used to move or agitate a material being treated, usually with great violence and with large expenditures of energy. The second set centers around those properties used to test a material, without changing its nature or condition. Here sound is used to "feel out" a material, to determine how hard or how heavy it is. The latter applications usually expend a relatively small amount of energy.

When vibratory energy is applied as the motive power in a process liquid, cavitation becomes a prime factor. Very high pressures and local agitation result, and in many cases elevated temperatures and electrical discharges accompany the phenomenon.

Cavitation in liquids is the alternate formation and collapse of gas bubbles or cavities. These form during the low-pressure part of the vibration cycle and collapse during the high-pressure portion of the cycle. It is the collapse of cavitation bubbles and the resultant high pressure that account for a great deal of the chemical and physical effects of high-intensity vibratory energy in liquids.

GLOSSARY OF ULTRASONIC TERMS

Electrostriction – A deformation produced in a material by electric stress.

Magnetrostriction – The property of a magnetic material causing it to change dimensions when placed in a magnetic field.

Interface – The boundary between two different mediums.

Absorption – Loss of sound energy to a medium because of change to other forms of energy, such as heat.

Absorption Coefficient – The ratio of acoustic power transmitted through a given interface area to the power incident.

Reflection – The return of sound waves from interfaces.

Divergence – The widening of a wave front as it progresses from the source.

Acoustic Impedance – Density of a material times the velocity of sound.

Acoustic Matching – Act of making the acoustic impedances of two successive mediums comparable in magnitude. (Example of poor matching, air to water; example of fair matching, water to rubber).

Refraction – Change of direction of a beam due to change in acoustic impedance of successive mediums.

Plane Wave-Sound Source – A source transmitting a wave having no divergence.

Spherical Sound Source – A bowl-shaped or ball-shaped source transmitting sound waves from either or both surfaces. This article considers only those examples where the wave is allowed to travel toward the center (focal point).

Cylindrical Wave-Sound Source – A source, cylindrical in shape, transmitting sound waves from either or both surfaces. The wave front is cylindrical, with the axis coinciding with that of the source. This article considers only those examples where the wave is allowed to travel toward the axis (focal region).

Longitudinal Waves – Waves in which the particle motion is parallel to the direction of propagation.

Compressional Wave – A longitudinal wave.

Shear Waves – Waves in which the particle motion is normal to the direction of propagation.

Torsional Waves – Waves in which the particle motion is on an arc of a circle normal to the direction of propagation.

Cavitation – Formation of cavities or bubbles by the liquid being torn apart. The ease with which these cavitation bubbles are produced depends upon the amount of dissolved gases present and the vaporization pressure of the liquid.

Resonance – Building up of sound intensity by a wave being reflected in phase with the transmitted wave.

Echo Reflection Method of Nondestructive Testing – Test method in which a short train, or pulse, of sound waves at high frequencies is aimed into the test object. Upon hitting an interface, some of the energy is reflected back to the source, where it is amplified and viewed on an oscilloscope screen.

Resonance Method of Nondestructive Testing – Test method in which an ultrasonic standing wave is set up in the test object between the source and the interface to be detected. This method is effective in measuring lamination or wall thicknesses.

Generating Equipment

Piezoelectric Generators. The most common ultrasonic generator used in laboratory experimentation is the piezoelectric type. It converts electrical energy into mechanical vibratory energy by the piezoelectric effect, which causes the material to alternately expand and contract in the presence of an alternating electric field. The piezoelectric effect is evident in a great many crystalline dielectric materials, but only those that exhibit the effect more strongly are used in ultrasonic generating equipment. Quartz is generally found in power equipment, although Rochelle salt, ammonium dihydrogen phosphate (ADP), and potassium dihydrogen phosphate (KDP) are also used. Fig. 1 shows a typical quartz crystal assembly suitable for laboratory use.

A relatively new material, barium titanate, is now being used as an ultrasonic generator. It is different from piezoelectric materials in that it is not crystalline and has no electric or optic axes. It is electrostrictive, however, and will shrink in whatever direction an electric field is applied. It can be made to act like a piezoelectric material by polarization in the direction the piezoelectric properties are desired. Because barium titanate can be molded in a great variety of shapes and polarized after molding, it is well-suited to applications in which focused sound waves are required. Dishes having a chord diameter up to one foot have been molded, Fig. 2, and thick-walled cylinders have been molded in diameters up to three inches and lengths up to six inches.

Compared to quartz, barium titanate has the advantage that lower applied voltages can be used to excite the material. This permits the use of simpler electrical equipment, and considerably reduces insulation problems in constructing a transducer. Titanate's disadvantages compared to quartz are its susceptibility to erosion by cavitation, the lower output levels per unit surface area that can be safely used, and

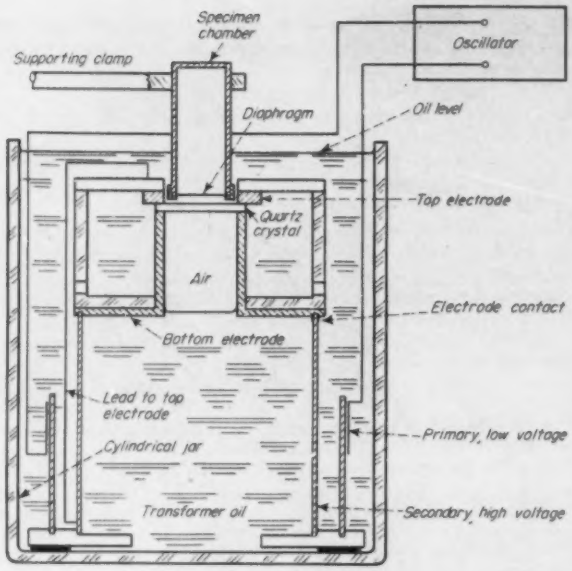
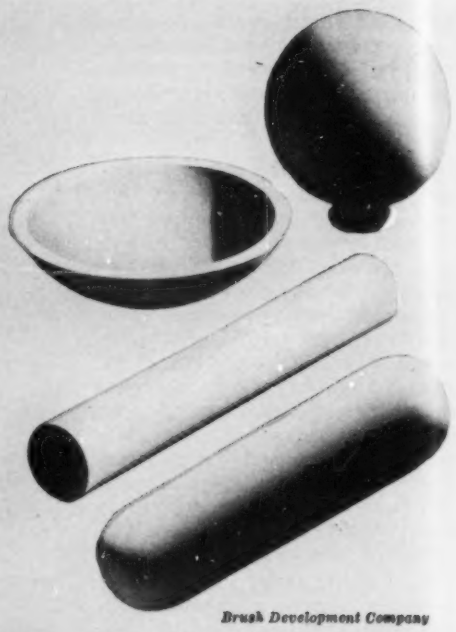


Fig. 1 – Laboratory set-up for subjecting specimens to ultrasonic energy has a silvered quartz crystal attached to bottom electrode which rests on the transformer assembly inside a cylindrical jar.



Brush Development Company

Fig. 2—Barium titanate piezoelectric generators can be molded to focus ultrasonic energy at a desired point or in a specific pattern.

the wide variations in its characteristics with temperature. Each of these limitations can be minimized by proper application.

Magnetostrictive Generators. The magnetostrictive effect, the change in dimensions of a material subjected to a magnetic field, is exhibited by many ferromagnetic materials. Again, only a few have been used widely as ultrasonic generators, the most widely-used being nickel and an iron-cobalt alloy called 2-V Permendur.

The usual form taken by a magnetostrictive generator is a tube or laminated stack, Fig. 3, surrounded by an exciting coil. Alternating current passing through the coil causes the material to expand and contract. As with piezoelectric generators, a rod or tube of the magnetostrictive material is excited at its mechanical resonant frequency.

The magnetostrictive generator compares favorably in most respects with piezoelectric generators in the lower frequency ranges, i.e., less than 100 kc. Typical operating range for power applications is from 8 to 30 kilocycles.

Pneumatic Generators. A third class of generators is the type that converts some other form of mechanical energy to vibratory energy. No electronic equipment is necessary. Instead, power for the generator is furnished by an ordinary pump.

The efficiency of some of these mechanical generators can be brought to a level which, in some cases, actually exceeds the overall efficiency obtainable with other types of generators. The nature of the equipment also lends itself to the construction of large units having high power output, as compared to electromechanical generators.

One promising liquid-phase generator is the underwater siren, which operates on the principle of directing a jet of fluid at a revolving disk or cylinder containing holes or slots. Liquid passes through the parts periodically, giving rise to pulses of moving liquid. Another is the underwater whistle, which periodically interrupts the flow of liquid by directing it against a vibrating knife-edge or into a resonant cavity.

Air-phase generators are useful for treating air-borne solids and aerosols in a process gas stream. Collection of liquids and solids from flue gases is an example.

The gas-phase generators most commonly used are those similar to the radio loudspeaker and siren. The industrial versions of these electrodynamic and siren generators differ greatly from their more familiar counterparts, chiefly in power output level, construction and size.

Experimentation With Ultrasonic Energy

It is advisable when planning experiments involving ultrasonics to determine (1) what specific physical effects are desired and (2) what range of exposure conditions is likely to produce the desired physical effects. Attention should be given to choice of

Fig. 4—When ultrasonic energy is expended usefully in a cavitated process liquid, the treatment region can be localized in three ways: (a) Close to the face of a plane-wave sound source; (b) at the focal region of a spherical or cylindrical-wave sound source; and (c) above a membrane that separates process liquid from any type sound source. Advantages of this third setup are that a material with good dielectric and thermal properties can be placed next to the sound source, even though process liquid has unsuitable properties; and that cavitation can be controlled.

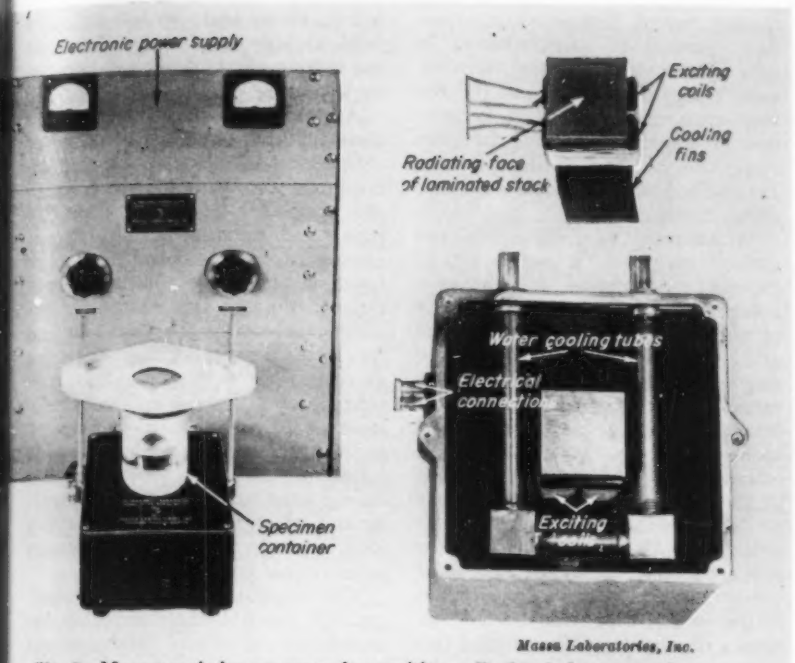


Fig. 3—Magnetostrictive generator has exciting coils that induce expansion and contraction of laminated-stack core under influence of alternating current. Cooling is handled by stack fins and finned tubing for circulating water.

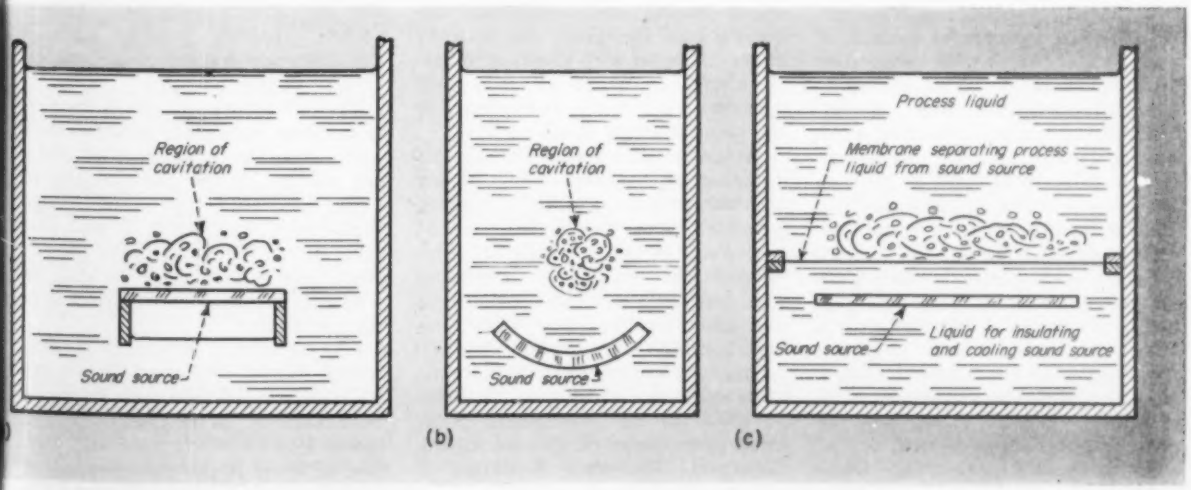
the correct equipment and experimental conditions. Care should also be taken when measuring the sound field applied and in interpreting the cause of observed effects. And most important is the evaluation of results in terms of the practicality of obtaining the same result on a much larger scale. This is generally a difficult task to perform correctly.

As an example of the physical effects that may be desired, cavitation may be known or suspected to be the cause of a useful effect such as emulsification of oil to form a paint base. The generating equipment is then designed to expose the process material to cavitation for the optimum time in an economical and uniform manner. To do this successfully several choices must be made.

Where will cavitation occur? In the simplest equipment setup, Fig. 4(a), the face of a plane-wave sound source is exposed to a liquid in a treatment chamber. Cavitation occurs in the limited region close to the face of the sound source. Liquid outside this region is not exposed to cavitation or to high-intensity vibrations because of the shielding effect of the cavitation bubbles. Therefore, the liquid is circulated so that its entire volume passes through the region in which cavitation occurs.

A spherical or cylindrical-wave sound source is shown in Fig. 4(b). Cavitation can be made to occur in the region in which the waves are focused. Advantages of this method are that the source can be operated at a lower intensity (power per unit area) and that the source is not subjected to the eroding action of cavitation. If cavitation is prevented near the source, the focusing of the vibratory energy makes it possible to obtain much higher intensity than can be obtained with a plane-wave source.

With equipment arranged as shown in Fig. 4 (c), a sound source of plane, spherical or cylindrical waves is used, and the liquid in contact with the energy source is separated from the process liquid by a membrane. This has several advantages. First, a material with good dielectric and thermal properties can be placed in contact with the sound source, even though the process liquid has entirely unsuitable properties. Second, the location of cavitation can be controlled. A pure, degassed liquid around the sound source will not show cavitation at sound intensities which are high enough to produce cavitation in a process liquid containing dissolved gases and other impurities. The two-compartment arrangement lends itself to pressurizing the chamber surrounding the sound source, to further discouragement of cavitation at the face of the sound source. This permits the source to be operated at the highest



practical energy density and, therefore, to deliver large amounts of vibratory power.

Resonance. As an example of choice of exposure conditions, consider the use of resonant treatment chambers. A resonant system is often used to obtain high values of alternating pressure, amplitude or acceleration at relatively low values of power input to the system. As applied to the ultrasonic treatment of materials, a resonant system uses a container that reflects energy back to the source each time the energy passes through the material being treated. The state of resonance itself is established by adjusting the operating frequency so that the reflected energy arrives at the source "in phase," or by adjusting the separation of source and reflector so that the same effect is obtained. In almost all cases, the sound source itself is operated at its resonant frequency.

Multiple reflections (or resonance) sometimes occur in a treatment chamber when they are not sought and often their presence remains unrecognized. This may account for lack of reproducibility of results when different placement of parts, different liquid levels above the source or other differences exist from one experiment to the next. Here, the exposure conditions should either be duplicated exactly, or preferably, steps taken to avoid multiple reflections entirely. This can be done by using sound absorbing screens, baffles or labyrinths, or by using a sufficiently long path to attenuate the reflected energy to a harmless level. For careful work, the effectiveness of such measures must be tested with a probe microphone or similar device.

Testing With Vibratory Energy

Considerable attention has been devoted in recent years to ultrasonic nondestructive testing. Many applications have proved highly successful and provide the best example, at present, of a thoroughly worth-while application of ultrasonic energy. The echo reflection and resonance methods are effective in showing voids in solid materials of most kinds. They are also reasonably sensitive to changes in grain or crystalline structure and, in some cases, show differences in composition.

The chief limitation to applying pulse and resonance instruments is the complex geometry of parts and high energy absorption of materials such as rubber, concrete and wood. Even these applications can be handled if equipment is modified to fit a given set of conditions. Fig. 5 shows how air cavities in tires can be located.

Many are the applications where quality control demands that a uniform product be manufactured. In some instances, propagation of ultrasonic energy through the material is a very sensitive indicator of its composition or physical condition. In other cases, selection and sorting processes are required that can be made sensitive with ultrasonic energy.

Measurement of particle size and surface roughness is worth special mention. Absorption of ultrasonic energy gives a rapid index of similarity of size distribution of basic particles or agglomerates. Variation in surface roughness, caused by normal process variations, corrosion or differences in composition, can be measured by ultrasonics, especially in a comparative manner. This is shown as a variation in scattering of the ultrasonic energy by the surface. When a transmitter is aimed obliquely at a test surface, there is a great difference in the amount of energy scattered back in the direction of the source, depending on the frequency of vibration. With a fixed frequency, a similar variation can be shown for differences in surface roughness.

Testing of dimensions has been applied in many cases where one side of a specimen is exposed. The methods used can be applied in various ways, using the same basic equipment, and a significant increase in accuracy of measurement obtained with refined equipment.

Mixing and Dispersion

Mixing and dispersion are "natural" applications of vibratory energy. The violent agitation that accompanies cavitation, and the circulating motion produced by pumping and thermal convection currents are capable of producing mixing and dispersing effects which are very difficult, if not impossible, to achieve by other means. Many mixing effects achieved with conventional equipment are obtained faster and better with vibratory energy. As always, the economics of a given application are equally as important as the physical effects produced.

A number of examples of vibratory agitation can be given. Solids of low cohesion such as mica, talc, gypsum, graphite, sulfur, and hematite can be dispersed, giving particles of semi-colloidal and colloidial size. Emulsion-type polymerization reactions can be accelerated by irradiation with ultrasonic energy. A magnetostriction oscillator at 15 kcps gives essentially the same results as a piezoelectric oscillator at 500 kcps. An investigation of the effect of frequency on solution stirring during the electrolytic deposition of nickel, shows that, at 560 kcps, 34 kcps, 15 kcps and 100 cps, a decreasing stirring effect occurs with increasing frequency.

An application of ultrasonic vibrations in the flotation dressing of various sulfide ores illustrates limitations that accompany the use of available equipment. Magnetostriction (20 kcps) and piezoelectric (300 kcps) generators, were used and the former found more suitable. But because of the extraordinary high energy requirements, the cost of the apparatus and the small capacity of the ultrasonic generator, the application was considered impractical. A different evaluation would have resulted had the experiments been performed at one kcps instead of 20 kcps, with a vibrator having some 50 times the power capacity and which was driven by a rotary electric power supply, rather than by an electronic power supply.

This example points up the dependence of practical applications on the availability of cheap, high-powered sources of vibratory energy. It further illustrates the reasons for a trend to lower operating frequencies, so that power requirements are lower, and simpler and less-expensive generating equipment can be used.

Agglomeration

Equipment for producing ultrasonic agglomeration is shown schematically in Fig. 6. The source of vibratory energy is placed at one end of a tubular enclosure and a sound reflector at the other. A resonant system with an intense sound field is established and the gas to be treated passed from one end of the tube to the other.

Solid or liquid particles are subjected to vibratory motion as they pass through the sound field. The amplitude with which they vibrate is controlled by their shape, size, density and surface condition. Larger, heavier, smoother particles undergo less vibratory motion than smaller, lighter, rougher particles.

The difference in motion of the particles causes many more collisions than would occur in the absence of vibratory energy. If the particles stick to each other when they collide, large agglomerates are formed. If solid particles do not normally adhere to each other, they can be made to stick by controlled introduction of moisture in the gas stream.

The mechanism of particle agglomeration is most important when gases are passed rapidly through the treatment chamber. In the cases of liquids, however, other effects come into play. One of these is the concentration of

particles at the velocity nodes in a standing wave system. Unidirectional forces developed in this system make the stable positions of the solid particles the areas in which the particles undergo the least motion. These positions appear every half-wavelength.

Product Cleaning

In industrial applications, some small cleaning units have already been installed in production lines. A specific example is an ultrasonically agitated bath for cleaning razor heads in the production lines of one manufacturer.

Several small-scale laboratory tests have been conducted using ultrasonic energy to clean both metals and clothing. Descaling and cleaning of metal pieces have been accomplished ultrasonically within a few seconds in a lukewarm solution, whereas the same work requires several minutes in a boiling solution when not treated ultrasonically. Equally encouraging results were obtained in the laboratory when washing cloth.

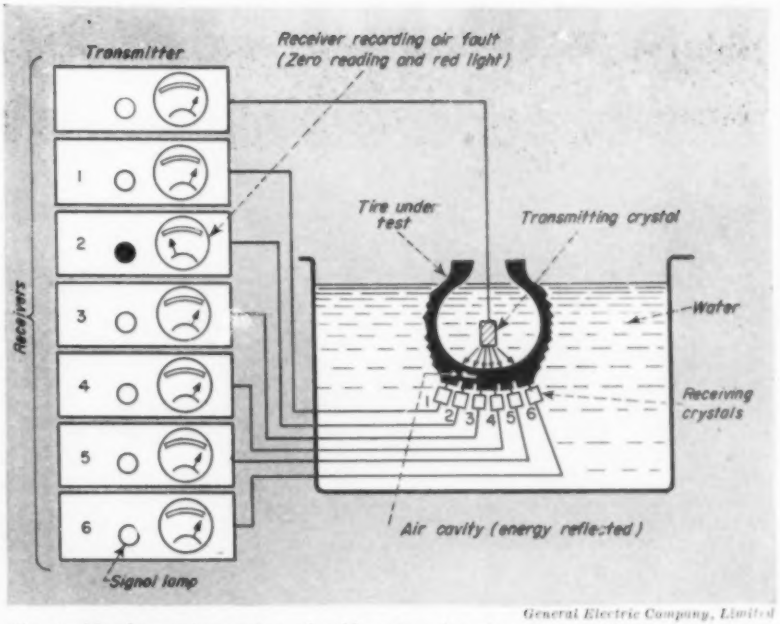
There are a few low-frequency vibratory washers being tested. An experimental unit at Battelle Memorial Institute has a small pan attached to the end of a 2,500 cps magnetostrictive vibrator. Materials such as metal, glass or cloth have been cleaned quickly and satisfactorily with this unit.

Frequencies of 30 kcps or less appear most satisfactory for cleaning materials thoroughly on all surfaces. Higher frequencies tend to limit the action to the surfaces facing the source because these higher frequencies are more directional.

Although cavitation encourages desirable reactions in cleaning metals, it greatly reduces the effective volume irradiated per unit area of radiating surface. A cloud of cavitation bubbles acts as a barrier to the transmission of ultrasonic energy. In laundering, an additional hindrance is provided by the cloth itself, which absorbs a great amount of the energy, thus reducing the amount available for other layers that may be present.

Cutting and Grinding

Ultrasonics has been used for drilling holes in hard materials and grinding in liquid suspension. At present, two methods of cutting or grinding specimens are being used. The first, tested extensively at Battelle Memorial Institute, is one in which the vibrating tool actually comes in contact with the work and the impact of the tool point against the work causes chips to be broken off. These chips are carried away by a stream of air or liquid. The second method, used when cutting very hard materials, is one in which very little contact is made between the tool and work. A fine grit suspended in a liquid carrier is washed across the face of the tool and the work-piece. The tool point imparts high accelerating forces to the particles causing them to beat against the work and knock chips from the piece. One advantage of this method is that the die can be made of comparatively soft material without being seriously eroded away or burned from excessive localized heating. Another advantage is that odd shapes are easily produced in materials that were previously considered impractical to cut by any other method. The rapid, short "punches" of both methods permit a smooth and accurate surface to be prepared even in extremely hard materials, thus increasing their utility.



General Electric Company, Limited

Fig. 5—Nondestructive testing of rubber tires for air cavities calls for both transmitting and receiving crystals. Water bath is used to produce a good transmission path between the crystals, as well as to achieve acoustic matching with the rubber.

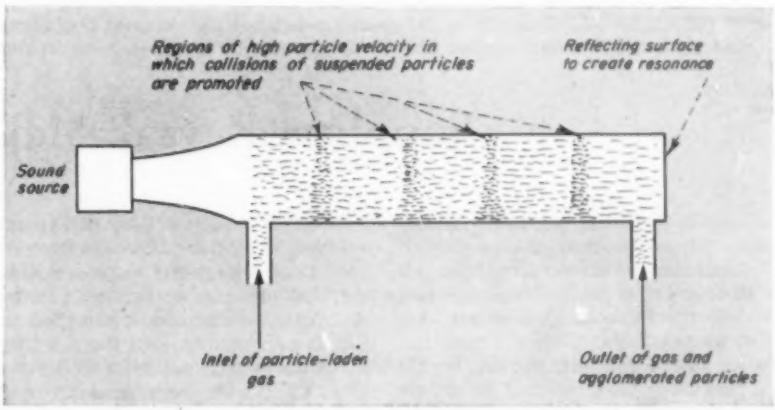

Regions of high particle velocity in which collisions of suspended particles are promoted
Reflecting surface to create resonance
Sound source
Inlet of particle-laden gas
Outlet of gas and agglomerated particles

Fig. 6—Ultrasonic agglomeration of suspended particles takes place in a resonant system. As particles pass through sound field, collisions are increased in regions of high particle velocity, thereby promoting the formation of agglomerates.

Future of Ultrasonics

There are a number of ultrasonic testing applications which have received little industrial attention so far, but which could prove of considerable importance in the future. These include measurement of such characteristics as: density, velocity of sound, particle size, dimensions, fatigue strength, modulus of elasticity, absorption coefficients, surface roughness, adhesion and cohesion. Many power applications also remain to be explored and developed.

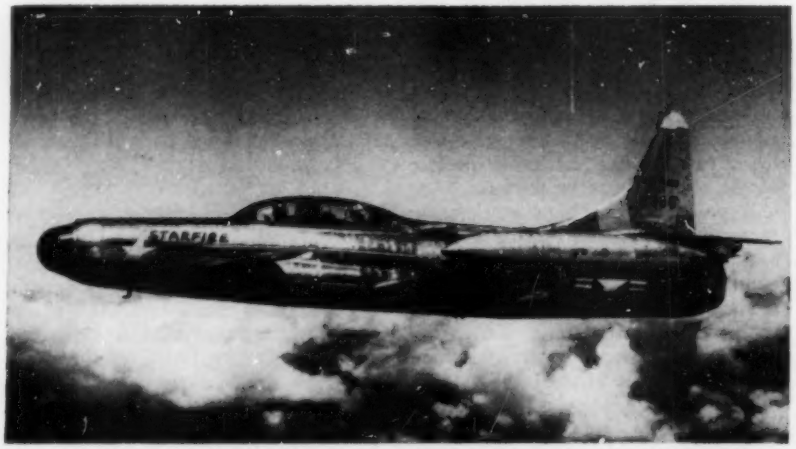
TECHNICAL NEWS

AIR FORCE F-94C STARFIRE is the most powerful single engine plane in production. Armed with 24 rockets mounted in the nose, airplane attacks and fires automatically in response to signals from electronic gear. Black nose houses radar equipment.

Suppliers Reveal: Major Defense Designs

DESIGNS FOR NEW AMERICAN FIGHTING MACHINES, long the subject of heated debate before Congress, are finally reaching production lines. Last month the Defense Department took the wraps off two of their newest and most potent weapons: the Air Force's supersonic F-94 C Starfire jet fighter and the Army's new Patton 48 tank.

Lockheed Aircraft Corporation developed the Starfire and have been in production for several months so that they are now making deliveries to the Air Force. Large scale production of the tank is underway in the Chrysler Corporation tank arsenal at Newark, Del., and production will be increased further when the Ford Motor Company, and General Motors start operations in a few months.



NEW JET FIGHTER is 41¼ ft long and has a wingspan of 37½ ft. Heavier than other jet fighters with a take off weight over 20,000 lb the Starfire is an all-weather fighter.

Key word in the design of the jet warplane is "automatic." Radar and specialized "brain-like" instruments enable the Starfire to spot an enemy airplane miles away, lock onto the target, track, close, aim, and open fire, without any help from the pilot. In fact the two-man crew, pilot and radar operator, may not even see the enemy plane they attack except as a pulse on the radar equipment.

The jet carries 1,200 pounds of electronic gear compared to 169 pounds carried by the Lockheed P-38 in World War II. One outstanding electronic innovation is a new automatic pilot.

Developed by the Westinghouse Electric Corporation with the Control Equipment Branch of the Air Material Command's Armament Laboratory, the pilot is the quickest acting and most sensitive instrument of its type ever put in use. It is closely related to tank stabilizers developed during the last war and uses three non-tumbling gyroscopes to obtain maneuverability when in operation.

The gyroscopes spin at about 12,000 rpm and are locked to the airplane

ARMY'S PATTON 48 has improved firepower with a 90 mm gun whose barrel can be replaced in the field. Machine gun over commander's cupola can be loaded, aimed, and fired from inside the tank. Elliptical hull and turret increase protection.

Begin to Reach Production Lines

so that they respond to the rate of change in angle of the craft instead of only the change in angle. Finger tip control is provided by a single spherical-shaped metal disk that can be moved to three positions.

During flight, when the disk is pulled back, the plane climbs at a constant rate regardless of external conditions; to turn, the pilot rotates the disk right or left and the rate of turn depends on the amount the knob is turned. When the disk is pushed forward, the airplane dives. The automatic pilot operates through a hydraulic system that multiplies the pilot's effort 15 times and conveys it to the control surfaces.

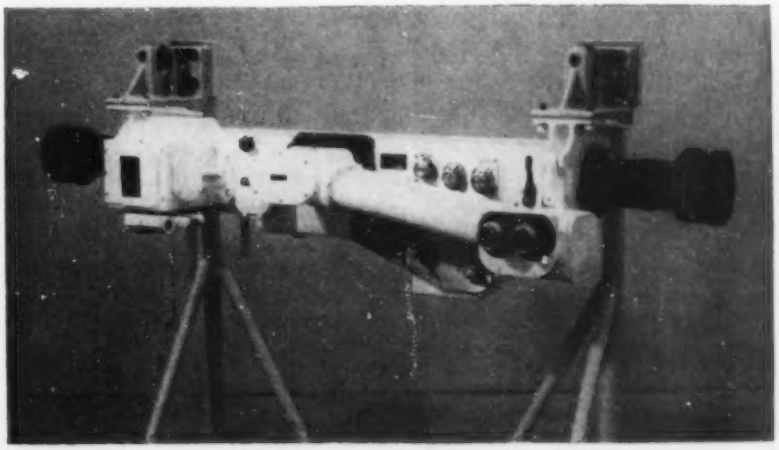
Equipped with a Pratt & Whitney J-48-P-5 jet engine, the Starfire is capable of a speed in excess of 600 mph and is one of the world's fastest climbing planes. In flight the jet produces a 6,250 lb thrust without afterburner. The thrust rises appreciably during rapid takeoff and combat maneuvers when an afterburner is used.

Aerodynamically, the new jet has a straight thin wing instead of swept-back contour. Lighter, but stronger than conventional supersonic wings, the sections are cut from one piece aluminum to eliminate rivets and small connecting parts.

A ribbon-type parachute, carried in a cylinder in the tail, can be released as the Starfire lands to reduce the landing distance required on short air strips. This is the first American fighter plane to use this equipment.

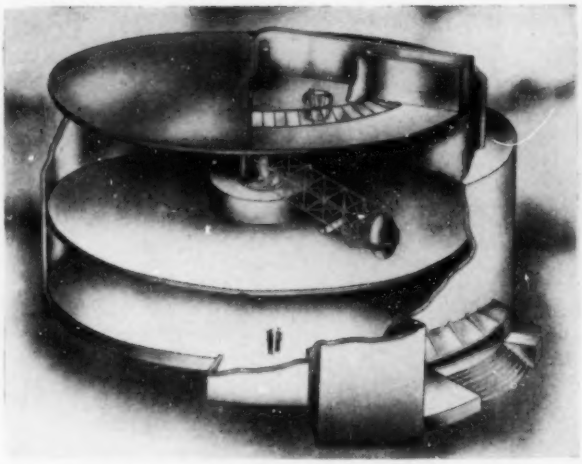
One ususual armament feature of the new fighter is the fact that it carries no guns. Instead, it is armed with a 24 air-to-air rockets housed in a ring of firing tubes around the nose. Accuracy is improved by placing the rockets as far forward as possible.

Air Force authorities feel that the

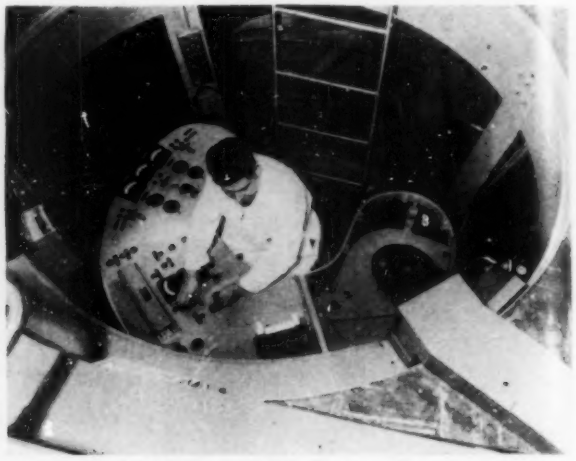


OPTICAL AND MECHANICAL RANGEFINDER controls firing of 90 mm gun on army's newest tank. Device extends gunner's depth perception thousands of yards.

World's Most Powerful Centrifuge



WORLD'S MOST POWERFUL MACHINE for subjecting human beings to the extreme gravitational conditions encountered in super-sonic aircraft is housed at the Naval Aviation Medical Acceleration Laboratory, Johnsville, Pa. Purpose of the laboratory is to evaluate human tolerance to acceleration and to study the psychological systems that limit this tolerance. Cutaway view of facilities show the location of the centrifuge machine at the center of the building. Floors, walls, and ceilings of the 120 ft dia centrifuge chamber are covered with $\frac{1}{8}$ in. copper to protect instrumentation circuits from magnetic and electrical interference. First tests are already underway.



CONTROL CONSOLE LOCATED IN BLISTER suspended from center of centrifuge chamber directs operation of machine. Since the test subject is visible to researchers only when the centrifuge is motionless, high speed television, X-ray, and motion picture cameras are mounted in the gondola so that studies can be conducted during an acceleration run. Slip rings mounted on the machine's rotor shaft link this recording equipment to control and observation stations. Turntable (right, under Lucite cover) holds operational cams that regulate centrifuge speed and acceleration in a predetermined cycle. Speed can also be controlled by lever in operator's left hand, or by the test subject.

Starfire is an intermediate step between the fighter planes of World War II, and completely automatic pilotless planes of the future.

Elliptical 48

The Patton 48 is the Army's newest tank in the 45-50 ton class and boasts the first one-piece cast hull built in the United States. Elliptical in design, the hull deflects enemy shells instead of permitting them to enter the tank.

Also cast in one piece is the turret which has elliptical sloping slides to provide the crew with more protection and better visibility.

A newly improved Ordnance-Continental air-cooled V-12 engine develops 810 hp to power tank, gun turret and communication equipment. A cross-drive transmission coupled with power steering makes the Patton 48 as easy to drive as a passenger car.

For firepower the new tank has a 90 mm high velocity gun designed to permit field replacement of the worn gun tube. Mounted coaxially with the main gun are cal. 50 and cal. 30 anti-personnel machine guns. Another cal. 50 machine gun is mounted over the commander's cupola. And for the first time, this gun can be aimed, fired, and reloaded from inside the tank without exposing crew members.

Mounted permanently on the tank is a precision optical mechanical range-finder that automatically sets the gun for the required distance. With this finder, the gunner ranges and continually tracks the target and can make adjustments for the type of ammunition being fired. Called the T-41 range finder, this device extends a viewer's depth perception thousands of yards beyond normal vision. It can be considered as a pair of telescopes mounted five feet apart.

When looking through the eyepiece of the finder, the gunner sees so-called retical patterns that resemble an overlay on the target image. One difficulty with this device is that it relies on consistent stereoscopic vision of the gunner. And this can be impaired by fatigue or psychological reactions.

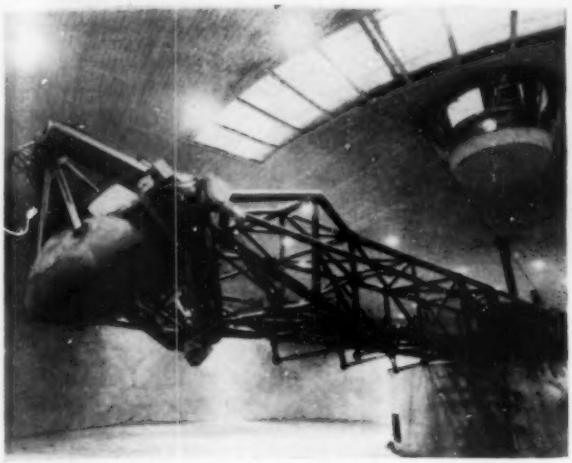
For greater flotation in swampy and muddy train, the Patton 48 has wider tracks than older tanks, and these distribute its weight over a greater area. While the normal complement of a medium tank is five men, the new tank requires a crew of only four: a tank commander, driver, gunner and loader.

Scientists Warn British To Use Industrial Research Or Go Broke

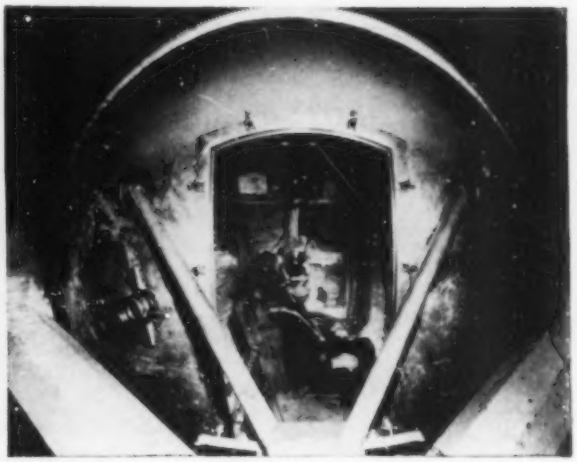
LONDON—British industry and government must drop its apathetic feeling towards scientific research or face bankruptcy and unemployment in the next few years. This pessimistic warning is contained in the annual report just issued by the Department of Scientific and Industrial Research. A government-sponsored body set up to organize and develop scientific and industrial research, DSIR's report views with grave concern Britain's failure to meet minimum post-war plans for research expansion.

In 1947 a minimum research program was set up to help Britain come through its economic difficulties. Aim of this program is to boost Britain's national income by increasing productivity, developing new and better products, and making better use of the country's limited natural resources. But the program has been seriously sabotaged by difficulties in building and recruiting, and lack of interest by industry, and government officials. As a result, the 14 research organizations

Studies Human Tolerance to Acceleration



CENTRIFUGE ARM, gondola, gimbals, counterweight, and gimbal controls weigh 84,000 lb. Centrifuge is capable of accelerating from a dead stop to 173 mph in less than seven seconds. It will speed up from zero to 90 mph in 1½ sec, and exerts a force on the test subject equal to 40 times the gravitational pull of the earth. Arm is rotated by direct connection to the 80 ton rotor of a vertical 4,000 hp d-c motor housed at its base (lower right). One of the largest vertical motors ever built, it is capable of developing 16,000 hp momentarily at 48 rpm. The centrifuge was built by the McKiernan-Terry Corp. and electric motors and control were supplied by the General Electric Company.



TEST SUBJECT is strapped into a spheroidal aluminum gondola suspended by double gimbals that can be rotated by motors mounted on the rotor arm. This permits the control operator to somersault or tip the human guinea pig into any position as he is whirled around the large circle described by the arm. Gondola is an oblate spheroid with a major axis of 10 ft and a minor axis of 6 feet. Its outer and inner shells are made of aluminum with a middle layer of a light cellular material. Wires wrapped around test subject lead to instruments that record measurements of his respiration, heart rate, blood pressure, heart waves, and brain waves. Gondola can simulate an altitude of 60,000-ft.

under the departments immediate control and the 41 autonomous research associations that receive grants have been unable to meet program requirements. And, Britain's economic position has failed to improve materially.

Appropriations and government red tape have been prime road blocks. For instance, almost $25,000,000 has been earmarked for the development of new organizations to carry out mechanical engineering research and hydraulic research. The report says that "Progress has been extremely disappointing," since the committee has spent over five years looking for a site on which to build the new facilities. While over 40 different sites have been examined and approved for the project, the department has been unable to secure the approval of the numerous local and central authorities involved for a single location.

Economy moves in Parliament have kept the program in a state of flux. Constant changing of appropriations have hit hard at projects that require several years for completion. DSIR warns that an essential research development program cannot be undertaken efficiently on a year-to-year basis, subject to sudden and unexpected cuts in budgets. And the facilities must be available before the country can reap any benefits.

The report adds that effective planning of research must be based on a reasonably firm budget setup for several years in advance. Many of the projects at DSIR require extensive capital equipment. Uncertainty as to delivery dates of equipment and materials and completion of buildings often makes it impossible to estimate the incidence of such expenditures in any one year.

Recruiting of research personnel has also slipped behind plans. When the program was set up DSIR expected to increase scientific investigators at the rate of 150 per year. For the past two years the average has fallen to 110, a growth that is inadequate to do the job necessary.

Progress of research projects assigned to the department are included in an appendix to the report. In raw materials, the agency has been working to help carry out the rearmament program and at the same time maintain the national economy. To raise industrial productivity and study the supply of materials, technical surveys were prepared on sulphur and sulphuric acid supplies, consumption of zinc and copper, and substitutes for non-ferrous metals.

A survey of wind power indicates that 10 percent of Britain's electrical power requirements can be satisfied by successful exploitation. Two medium-size generators have been set up to obtain operating data, and smaller generating units are being planned for other sites.

The Motor Industry Research Association, operating on a DSIR grant, has completed an automobile proving ground. Facilities here include a "Belgian Pave" stretch for acceleration testing, a 40 ft tank for splash testing of a vehicle's fording ability, a pitching track for studying suspensions, and a steering pad for evaluating steering gear. Object of this facility is to provide better military vehicles and to improve the quality of British autos so that they can compete more favorably in foreign markets.

Another grant has resulted in the development of a new pulping process that turns whole wheat straw into pulp for writing paper. Full scale trials have worked satisfactorily in a commercial paper mill and actual production is planned in the near future.

TESTING: Fluorescent Ink Spots Cracks

MANCHESTER, ENGLAND—Fluorescent ink and ultra violet light are combined in a new technique for detecting surface cracks and flaws in light metals, non-ferrous alloys and plastics. Using an ink called Glo-Mor, the process can be employed where magnetic methods are impractical.

Fluorescent crack detection consists of painting the surface of the test piece with ink and then viewing it under ultra violet light. Large pieces like aircraft structural members, and welded sections can be inspected in place. Cracks and holes in hydraulic systems can also be spotted in this manner.

First step in the procedure is to clean and degrease the part. The fluorescent ink, developed by Manchester Oil Refinery Ltd., is applied to the surface by dipping it in a tank of the ink, pouring or brushing ink on the surface. After allowing one minute for drying, the piece is inspected under the light of a portable ultra violet ray lamp.

Surface cracks reveal themselves by a brilliant green fluorescence, standing out against a background of fluorescence on the surface of the test piece.

IN ORDINARY LIGHT the surface of this anodized turbine blade looked free of cracks and imperfections.

IN ULTRA VIOLET LIGHT this transverse crack appeared after the surface was painted with fluorescent ink.

The pattern of the crack is more clearly defined when this background is removed by a quick dip in carbon tetrachloride.

Cracks extending through the cross section of the piece can be detected by viewing the unpainted face of the test piece under the ultra violet. This method is also effective when checking parts for porosity.

Glo Mor is not toxic and the inspection can be carried on in diffused daylight since inspectors do not require special glasses to make the test.

Congress Removes Professional Engineers from Salary Control

JULY AMENDMENTS TO THE DEFENSE PRODUCTION ACT have removed an estimated 400,000 professional engineers from wage and salary controls. But despite a clarifying announcement from the Office of Salary Stabilization, there is some confusion as to who is concerned.

In the order detailing who is exempted from such controls, OSS defines a professional engineer as *"a person who, by reason of special knowledge of the mathematical and physical sciences and the principles and methods of engineering analysis and design, acquired by professional education and practical experience, is qualified to apply such special knowledge for the purpose of rendering professional services or accomplishing creative work, such as consultation, investigation, evaluation, planning, design, or supervision of construction for the purpose of assuring compliance with specifications and design in connection with structures, machines, processes, works or projects."*

According to the order, a person may become qualified: (1) by reason of his professional education if he holds a *professional engineering degree* from a college or university authorized to grant academic degrees in *professional engineering*. Or (2) by being licensed or registered to practice as a professional engineer in any state, territory, or possession of the United States or in the District of Columbia.

Definitely excluded from the release are the following people: (1) persons engaged in carrying on routine mechanical activities; (2) persons employed as technicians or artisans no matter how highly skilled; (3) advisers on sales promotion, business methods, and operation; (4) persons whose occupation are designated as that of "engineer" such as stationary engineers, maintenance engineers, sales engineers, or management or administrative engineers; (5) physicists, chemists, mathematicians, and other persons professionally employed in scientific fields, even though their activity may be be closely related to professional engineering; (6) persons designated as engineering assistants, engineering aides, junior engineers, or other engineering personnel who work with professional engineers but are not qualified to do the work of professional engineers.

OSS warns that the professional engineer must be employed in a professional capacity to be exempt from wage controls. The release does not apply to a person qualified as a professional engineer but employed in the capacity of an executive rather than a professional engineer (for example, vice-president in charge of sales of a machinery distributer) or if the engineer's primary duty is administrative (such as employment manager in charge of recruiting and placement of professional employees) the release does not apply.

Joseph D. Cooper, executive director of OSS warned employers with salary plans that "granting increases to professional engineers under this exemption will not be a basis for modification of the plan with respect to granting raises to other employees."

He added, "Under our regulations, provision is made to allow

an employer to maintain customary and historical relationships. However, an employer who raises the salary of a professional engineer, now exempt, and then on the basis of this increase attempts to restore the historical relationship between this engineer and those he supervises through salary adjustments, violates our regulations."

Cooper attempted to discourage employers from using the new order by warning them against disrupting other "historical" relationships.

Nylon Powder Sintered

THE POLYMER CORPORATION of Reading, Pa., announces the development of a finely divided nylon powder that is suitable for cold pressing and sintering techniques similar to those of powder metallurgy. Called "Nylasint 66," the powder is produced by a special chemical process that keeps particle size smaller than 10 microns.

By using this new technique instead of injection molding, the nylon powder is processed below its melting point so that there is less tendency for internal stesses to develop and dimension stability is increased. In addition, the process permits a uniform blending of nylon with fillers to obtain specific thermal and hygroscopic expansion properties, or to obtain special electrical characteristics.

Tests have indicated that bearings made by cold pressing and sintering nylon powder have a low coefficient of friction that make them useful for operation without lubrication.

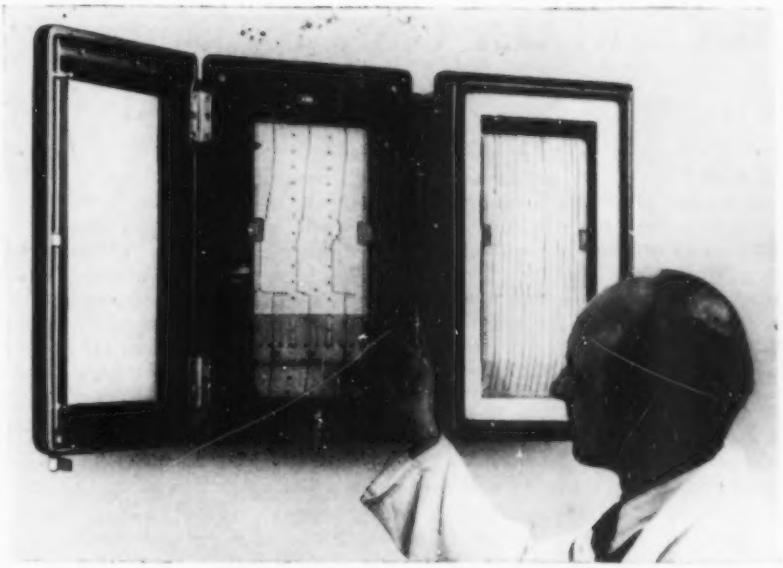
The process lends itself to the sintering of nylon bearings, gears, cam rollers, and valve seats. The sintered product has similar chemical, hardness and wear resistant properties, but lower toughness than found in molded products.

Yale & Towne Enters Powdered Metal Field

YALE & TOWNE MANUFACTURING COMPANY has purchased the American Sintered Alloys, Inc., manufacturers of sintered powdered metal products used as components in the end products of other manufacturers, in exchange for Yale & Towne stock.

They plan to operate ASA as another of the company's divisions and to continue the sale of sintered metal components to other manufacturers through Eugene P. Pack & Associates.

The purchase puts the hardware and materials handling equipment manufacturer into a third sales market.



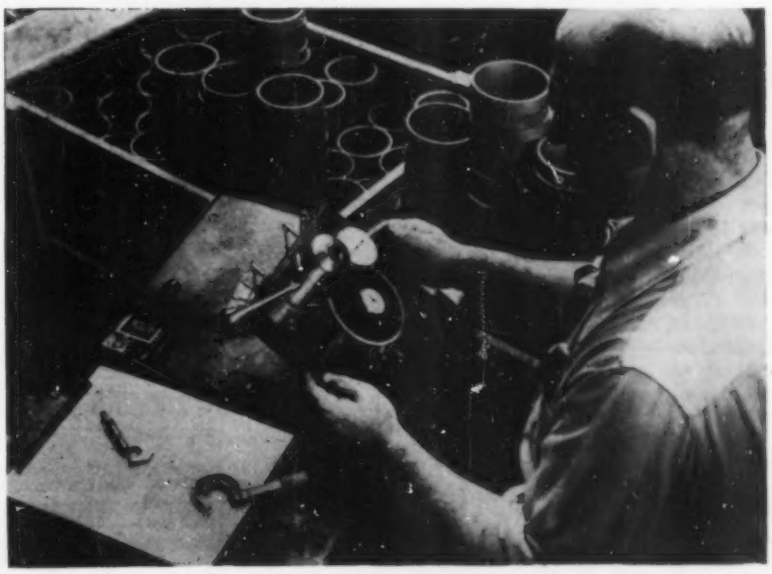
Recorder Uses Electrode Instead of Pen

FRANKFURT — Allgemeine Elektrizitaets-Gesellschaft has developed an electrical recording device that uses a thin pin electrode instead of the nib of a pen to produce a trace. The device permits a writing speed of several feet per second with negligible wear.

Replacing the pen nib eliminates nib maintenance and provides an improved trace by preventing drying up and uneven flow of ink.

Resting lightly on the surface of the metal recording strip that is backed up by a second large area electrode, the pin electrode burns into the metal recording strip to produce a burnt out line when a voltage of 20 to 24 v passes through the electrodes.

The recording can be read by illuminating the strip from the reverse side or by covering the tape with a length of frosted glass. It can be copied with prolonged time exposure by conventional reproduction processes.



SPECIAL TWO-WAY GAGE designed by Chase Brass & Copper Company inspects wall thickness and depth of copper rotating bands used on artillery projectiles. Dials indicate wall thickness and depth continuously as the inspector turns the band. Gage replaces two hand micrometers (lower left) and makes more complete inspections.

MATERIALS: U.S. Expansion Programs Set All Time Record

WASHINGTON—U. S. industry will spend close to 60 billion dollars by 1955 to increase the supply of materials, many of which are currently in the critically short category. The Defense Production Administration released this information in a report on the mobilization program.

According to DPA about 52 percent of the planned new facilities are now in place and the expansion program will be 94 percent complete by the end of 1953. Here is how the program will affect U. S. supplies of major materials:

Lead: By 1955, production will reach 1.3 million short tons per year, a 10 percent increase over 1949.

Zinc: By 1955, production will equal that of lead, 1.3 million short tons a year, representing an 18 percent increase of 242,000 tons over 1950.

Petroleum: Crude petroleum production will be up to 7.8 million barrels a day by 1953. In 1950 production was 6.4 million barrels, and it will rise this year to 7.2 million per day.

Steel: New steel facilities will boost annual production from 100 million tons before Korea to 120 million tons in 1954. By the end of 1952, steel production will be up to 108 million tons.

Nickel: A twenty three percent increase will boost nickel supplies to 132,000 short tons, domestic and imports, by 1954. This is 30,700 tons more than 1950.

Manganese Ore: In 1954, domestic supplies and imports will be 2.5 million long tons, a 25 percent increase over 1950 supply.

Sulphur: 8.4 million long tons will be produced in 1954, increasing supplies 27 percent over 1950.

Chlorine: Defense mobilization needs chlorine and supplies will be boosted 37 percent by 1955 when facilities will produce 3.4 million short tons.

Phosphorus: In 1955, productive capacity will have increased 37 percent and suppliers will be turning out 275,000 short tons a year.

Cobalt: This material remains one of mobilizers' top problems despite a planned increase of 44 percent over 1950, to 18 million pounds a year by 1954. Use of cobalt continues to increase faster than production.

Tungsten: By 1954, production will have been increased 50 percent over 1950, and domestic and imported supplies will be 26 million pounds a year.

Molybdenum: Despite a 51 percent increase over 1950 that will make 1955 supplies 58 million pounds, molybdenum may still be in short supply since a flood of new applications are being developed particularly in high temperature and aviation fields.

Aluminum: Biggest percentage increase is planned for the mushrooming aluminum industry. Between 1950 and 1955, the U. S. will double primary output. In 1952 production is expected to reach 1.1 million tons, and 1.5 million tons in 1955. But government planners say that this whopping increase may not be enough to keep up with the increasing use of the light metal, and plans are being studied to boost aluminum supplies still further.

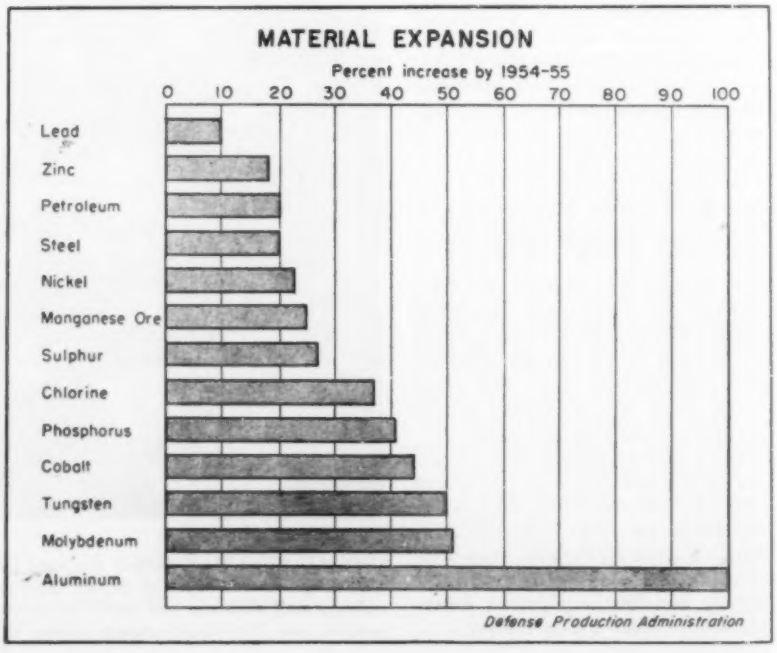
While the U.S. expansion program is impressive, there are certain physical limitations imposed particularly where foreign supplies are involved and where it is difficult to increase our own production because of dwindling natural resources.

International agreements regarding imports of certain critical materials could upset the schedule. For instance, the copper program is in a state of flux because of Chile's reneging on their contract to supply a big share of U. S. needs (PRODUCT ENGINEERING, June 1952, p. 115). While the situation has been remedied temporarily with a double price standard, DPA officials feel that industry cannot live with this arrangement for any long period of time. Tin supplies also remain on a year-to-year basis.

Almost simultaneously with the release of DPA's report, the President's Materials Policy Commission issued a five volume report attempting to forecast the U. S. requirements for materials in 1975. PMPC envisions huge increases in the use of all materials by that date, and believes that U. S. industry will be able to supply the needs.

According to PMPC, aluminum is the metal of the future. Demand will be up 358 percent by 1975 when industry will be using 4½ million short tons of the light metal per year (scrap will supply 900,000 tons). 1950 consumption of aluminum was less than one million tons. Next biggest increase in material use is the expected jump in demand for cobalt. In 1950, the U. S. used 9 million pounds; presidential planners predict that industry will need 40 million by 1975.

Other materials and their percentage increases over 1950 consumption as reported by the planners include: Copper, 45 percent to 2,500,000 tons; lead, 61 percent to 1,950,000 tons; zinc, 38 percent to 1,600,000 tons; tin, 27 percent to 118,000 tons; antimony, 76 percent to 66,000 tons; nickel, 100 percent to 200,000 tons; molybdenum,



170 percent to 70,000,000 lb; tungsten, 150 percent to 15,000,000 lb; rubber, 104 percent to 3,300,000 tons.

Big increases are expected for iron and steel products too: finished steel will be up 62 percent to 110,000,000 tons; crude steel products, 55 percent to 150,000,000 tons; and pig iron increased 54 percent to 100,000,000 tons.

The commission warned that these demands could be met only if extensive exploration for new resources was undertaken, and new processes developed for using low grade ores. They also recommended government stockpiling of certain of the materials.

Copies of the report may be purchased from the Superintendent of Documents Government Printing Office Washington 25, D. C.

Navy's Bismanol Makes Powerful Permanent Magnets

NAVAL ORDNANCE LABORATORY at Silver Springs, Md. has developed a new magnetic material that exhibits a coercive force of 3,000 oersteds, the highest recorded force of any known permanent magnet material. Called Bismanol, the material was developed during a search for a magnetic material that does not contain nickel or cobalt.

Because of this high coercive force, the new magnets exceed any other permanent magnets in available flux density (except for platinum cobalt alloys) in short magnets where length to diameter ratio is one or less. They also exhibit an energy product comparable with Alnico magnets ($3X10^6$ gauss-oersteds) and a Curie temperature of 350 C.

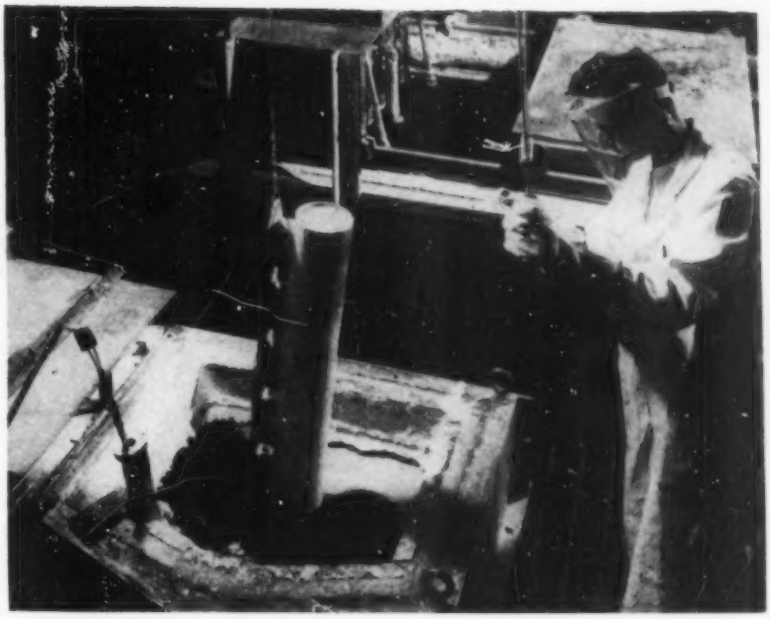
Bismanol is manganese bismuthide, an intermetallic compound. And while both bismuth and manganese are non-magnetic when alone, this particular combination possesses high magnetic crystal anisotropy since it has an axis along which magnetizing is very easy as opposed to one or more axes along which it is difficult. Permanent magnets are made by taking this characteristic in account and aligning the crystals in the direction of easy magnetism.

The magnets are made by powder metallurgy. Powdered manganese and powdered bismuth are mixed and heated to about 1,300 F. The mixture is cooled to 750 F and aged at that temperature for from eight to 16 hours. At this stage, the alloy consists of the intermetallic compound manganese bismuthide and unreacted manganese and bismuth.

A magnetic separator removes the compound from the mixture after it has been pulverized. The magnetic portion is then hot pressed at a temperature of 575 F. in a double acting floating die that is in a strong magnetic field to align the particles along the direction of easy magnetism.

Because powder metallurgy techniques are used to fabricate the final magnets, complicated shapes can be processed to close tolerances without additional machining.

NOL is currently evaluating the new magnets with respect to temperature, stability, aging, and shock properties. This study is aimed as uncovering possible defense uses for the new material. At present NOL feels it will be useful in several electronic miniaturization programs.



ALUMINUM COATING applied inside and outside of fabricated steel manifold increase lift of part by improving corrosion resistance. After cleaning, part is dipped into molten aluminum that is protected by a layer of molten salt.

Aldip Process Coats Ferrous Metals With Aluminum

GENERAL MOTORS RESEARCH LABORATORIES have developed a new process for coating ferrous metals with aluminum that increases parts resistance to corrosion by heat and acids.

GM claims that this process is one of the first that is simple and inexpensive enough to be used for coating individual parts or in a continuous process for coating sheet, wire, or rod stock. Here's how the coating is done:

First step is cleaning to remove grease, oil, paint, dirt, scale or carbon smear (if cast iron parts are being treated). The part is dipped in an alkaline cleaner, washed in hot water, run through an acid pickle, rinsed in cold and hot water and then dried.

Next they are dipped for about four minutes in a bath of preheating salts at temperatures ranging from 1,280 to 1,400 F. Then they are transferred to an aluminum bath which is covered by a layer of salt flux about one-half in. deep. The part remains in the aluminum bath for 30 seconds to a minute.

While still hot, the parts are returned to the preheat salt bath and slowly raised.

Properties of the aluminum-coated steel vary with steel composition and preparation, aluminum alloy composition, time of dip, temperature of dip, and subsequent heating of the coated material. Microscopic examination of Aldip on steel has revealed that an iron-aluminum alloy forms next to the steel, and the outer coat is aluminum-bearing iron.

GM reports that the coating has increased the life of such parts as automobile muffler tube assemblies, exhaust tail pipes, steel hangers, paint rack fixtures and other parts subject to corrosion by intense heat and acids.

—Aviation Week

RUSSIAN MIG-15 as drawn by Air Force artist. Jet fighter is capable of a top speed of 672 mph and can climb at the phenomenal rate of 10,400 ft per minute.

Captured Russian MiG Shows Top Notch Engineering

SOVIET ENGINEERING and fabrication demonstrated in captured MiG-15 airplanes is excellent and in many instances comparable to American standards and practice. This is the conclusion reached by the Air Force in the official USAF evaluation of the MiG recently released. Prepared by engineers of Pratt & Whitney Aircraft Division of United Aircraft Corporation, USAF technical specialists at Wright-Patterson Air Force Base, Cornell Aeronautical Laboratory and other government research organizations, the analysis is concerned with the MiG-15 built in 1948 at Zabod 1, Kuybyshev.

Performance

Top speed of this jet fighter is 672 mph, and its rate of climb is an amazing 10,400 ft/min. Weighing only 12,500 lb (compared to 16,500 lb for the U.S. F-86 which is in daily Korean combat with the MiG), it has advantages in climbing and maneuverability. Korean veterans have reported that its performance above 30,000 ft is "phenomenal."

Fuel capacity of early models is about 330 gal, though later versions have facilities added for carrying droppable external wing tanks that increase flying range considerably.

Three versions of the MiG have been seen in Korea. Similar in configuration, the main differences have been in their power plants. Latest MiGs are powered by Russian versions of the British Rolls-Royce Nene Engine that developed 5,000 lb thrust. However Soviet engineers have squeezed an additional 1,000 lb thrust from the basic English design, and with water injection, have boosted output to 6,750 lb thrust.

The engine is a continuous-flow turbojet that has a single-stage double entry centrifugal compressor, with a 28.8 in. dia machined impeller and 29 radial vanes of each side. Impeller and impeller-inducers are made of aluminum. The inducer sections measure 17¾ in. in dia and are included on both sides of the impeller.

The compressor casing assembly is made of aluminum alloy and consists of a front and rear member to which the diffuser sections are attached.

Each of the combustion chamber assemblies is made of a chamber of aluminized steel, a cover of cast aluminum, and an inner removable liner of high-temperature-resistant alloy. Fuel is injected downstream by means of an atomizing fuel nozzle. A combustible mixture is formed when primary air is admitted through a metering orifice in the front end of the liner. Primary air velocity is reduced by means of a swirl vane assembly that surrounds the burner and assures flame stability.

Secondary air flows along the annular space between the liner and the combustion chamber and is directed through holes into the interior of the liner to dilute the gas mixture and reduce gas temperatures before it reaches the turbine element.

Ignition is accomplished by two flame igniters that consist of a low pressure atomizer and high tension spark plug.

The turbine wheel assembly is made of a 16 in. dia disk, machined from a steel alloy forging. It includes 54 equally spaced V-shaped slots whose sides are broached to form a series of truncated "fir tree" splines for turbines blade mounting.

Axial movement of the blades is restricted by a key, formed integrally with the front end of the blade root. The turbine nozzle guide assembly includes 48 blades of high temperature resistant material.

Russian development of the Nene indicates that the Russian powerplant is not just a copy. They increased the area of the combustion chambers by 15 percent and made the turbine blades longer and of wider chord. The final tailpipe area of this version is 30 percent greater than the original. And despite these increases in area, Russian engineers were able to hold the outside diameter of the engine to the original 50 inches.

Materials used in the Russian power plant are similar to those used in the Rolls Royce engine and in the Pratt & Whitney J-42. Turbine blades are made of a stainless steel alloy known technically as Nimonic 80, and the burner liner and swirl vanes are Nimonic 75. The swirl vane assemblies are fabricated of titanium-stabilized stainless steel in both outer and inner rings. Use of this material in turbine blades and after burners makes practical an engine operating condition at turbine inlet of 1,550-1,600 F.

The Soviets overcame one design problem in air dilution that has been an insurmountable obstacle for British and U. S. engineers. Increased dilution of air is obtained in Russian power plants by the addition of a ring of perforations just behind the primary zone of the combustion chamber.

Other impressive Soviet design

changes include addition of reinforcement rings in the liner perforation of the combustion chamber hot zone to boost strength; an increase in the gage of metal used in the hot zone and liner section; and an improved duplex fuel nozzle.

These design changes increased the weight of the power plant from 1,715 to 2,000 lb. Specific fuel consumption is 1.14 lb per lb of thrust per hour with no afterburner. However, the tail pipe diameter and length are sufficient size to use a short afterburner that would boost thrust 1,000 pound.

Most impressive production technique noticed on the Soviet engines was the apparent proficiency of fabricators with resistance welding, particularly when welding three different thicknesses.

Structural Design

Unlike the Airforce's new Starfire, the MiG has a sweptback wing with a 42 deg angle. It's wing span is 33 ft and incorporates conventional control surfaces. The horizontal tail surface spans almost 15 ft and is also swept back 42 degrees.

An internal sealed aerodynamic control balance installed on the aerilons is used to reduce pilot stick force, and allows a maximum effective control area. However it limits the throw of the stick and the effectiveness of the aerilons.

Two stall fences approximately 4 in. high are located on the upper surface of each wing, parallel to the line of flight. These fences extend from the wing leading edge to the flap-aerilon hinge line.

The horizontal tail surface has a serrated plate at the forward attachment point of the horizontal stabilizer to provide ground adjustment of the angle of incidence. A steel plate acts as a mass balance and is located at the bottom of the rudder assembly. And an additional mass balance weight is provided at the tip of the rudder.

Fuselage of the Russian fighter is of conventional semi-monocoque construction with stressed metal skin used throughout. The sections are built of pressed aluminum formers, extruded stringers and aluminum skin. The nose and mid-section containing the pilot's compartment and fuel cells compose the forward assembly of the fuselage that ends at the intersection of the rear wing spar and the side of the fuselage.

At this point is located a steel carry-through structure in the form of an I section with steel caps joined by a web consisting of two aluminum plates bolted and riveted to the caps. The rear section of the fuselage bolts to this structure.

Forward and rear spars of the wing are built up I sections of aluminum alloy with extrusions for the upper and lower caps. The diagonal bar is similar in construction to the carry-through structure and transmits bending load to that structure.

Two mass balances are located in the leading edge near each wing tip, weighting about 60 lb each. These prevent the appearance of a critical flutter frequency in the allowable range of flight speed, by increasing the speed at which flutter occurs.

Instrumentation

Cockpit controls include a combination voltmeter and ammeter, a remote compass indicator, a tachometer, a fuel gage, an engine gage, and 15 instruments for controlling lights and minor devices.

The remote compass indicator transmitter is located five feet inboard from the right wing tip. Fuel indications are made by a float type fuel indicator transmitter that uses a potentiometer and a sliding contact to transmit a voltage signal proportional to the tank fuel level.

In the engine gage unit there are three galvanometer units in a single case to indicate fuel pressure, oil pressure, and oil temperature.

The control console is composed of three major sections. On the left console are the throttle flap and dive brake control handles, circuit breaker for starter and ignition system, fire extinguisher controls, and the volume and tuning controls for the radio.

A small panel in the forward section of the console carries a fire warning light, and two actuator buttons controlling a two shot fire extinguisher system. On the right left console are carried the majority of the radio controls, and the valves for emergency landing gear and flaps.

Major differences in design between the MiG and American fighters are in armament and electronic gear. The Soviet government has more regard for fighter performance than for pilot safety. The Russians use a minimum of protective armament and electronic gear while USAF fighters are heavily protected and carry as much as 1,200 lb of gear (See Starfire story on p. 186).

An example of Russian thinking along this line is illustrated by an experience in World War II. Russia took 6,000 Bell P-39 Aircobras under lend lease terms and immediately discarded armor plate, reduced the number of machine guns, and removed considerable instrumentation thought necessary by the U. S. for pilot safety. Result was a weight saving of more than 3,500 lb. And, what the Air Force had begun to consider a second rate plane became more than a match for anything the Germans could use on the eastern Front against the Reds.

For firepower, the MiG has two 23 automatic cannon on the lower left side of the nose, and one 37 mm automatic cannon on the lower right side.

Of the three types of MiGs, only one is equipped with radar and that for night combat. The only electronic equipment they carry is a navigation and communication receiver, and an airborne homing receiver. Both receivers are Soviet designed and are high quality in manufacture.

MiG-15	VS	F-94-C Starfire
Weight	12,500 lb	20,000 lb
Wingspan	33 ft	37½ ft
Wing Design	Sweptback 42 deg	Straight thin wing
Speed	672 mph	Over 600 mph
Electronic Gear	Under 150 lb Radio equipment only	1200 lb Radar, automatic pilot, instrument landing system, etc.
Fire Power	Two 23 mm cannon One 37 mm cannon	24 2¾ in. air-to-air rockets
Jet Engine Thrust (without afterburner)	6,750 lb	1,250 lb
Cabin	Pressurized	Pressurized and temperature controlled with ejection seats and jettisonable canopy.
Combat Operation	Depends on pilot	Automatic, electronically controlled.
Type Operation	Day	Day, night, all weather

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Allowable Design Loads for Aluminum Columns

MARTIN A. RUBINSTEIN
Bristol Engineering Corporation

These nomograms are based on recommendations in the government document, ANC-5, Strength of Metal Aircraft Elements. They use Euler's equation for long columns and, depending on the material, either Johnson's parabolic or straight line equation for short columns.

Euler's Equation $F_c = \dfrac{c\pi^2 E}{(L/\rho)^2}$

Johnson's generalized equation $F_c = F_{co}\left[1 - K\left(\dfrac{(L/\rho)}{\pi\sqrt{\dfrac{cE}{F_{co}}}}\right)^n\right]$

The value of n, which determines whether the short column formula is the straight line or parobolic type, is selected from Table I. As usual, the transition from the long to short column range is given by

$$\left(\frac{L}{\rho}\right)_{cr} = \pi\sqrt{\frac{k\,c\,E}{F_{co}}}$$

where:

F_c = allowable column compressive stress
F_{co} = column yield stress and is given as a function of F_{cy}, (compressive yield stresss).
L = length of column
ρ = radius of gyration of column
E = modulus of elasticity—noted on nomograms
c = column end fixity from Fig. 1.
n, K, k = constants from Table I.

Nomogram I applies to 14S-T4, 24S-T3, 24S-T4 and 61S-T6 alloys. Nomogram II is for 14S-T6 and 75S-T6. Each of the two give the value of F_c for columns of tubular cross section when L/ρ, c and F_{co} are known. The first step is to determine $(L/\rho)_{cr}$ by drawing a line tangent to the appropriate c curve for short columns at the given value of F_{co} and extending it to intersect the L/ρ scale for short columns. The value at this intersection is the critical one. The magnitude of F_c is obtained by drawing a straight line from L/ρ on the proper scale (long or short columns) through the point on the c curve.

Example: A column of tubular cross-section is made of 14S-T4 aluminum. F_{co} = 39,800 psi, c = 2 and L/ρ = 66. Find the maximum load.

Solution: Since the alloy is 14S-T4, Nomogram II must be used.

(1) From Line I, $\left(\dfrac{L}{\rho}\right)_{cr} > 100$, so the column is short.

(2) From Line II, F_c = 25,800 psi.

Example: A column of tubular cross section is made from 75S-T6.

F_{co} = 74,200 psi, c = 1.5 and $\dfrac{L}{\rho} = 90$.

(1) From Line III on Nomogram I, $\left(\dfrac{L}{\rho}\right)_{cr} = 63.9$. Thus, the column is long.

(2) Line IV on the same chart shows F_c = 19,300 psi.

Both nomograms, however, as well as the values of F_{co} in Table I, are derived for columns of tubular cross section. For short columns of other stable shapes, an empirical procedure that is usually conservative is commonly used.

The crippling stress, F_{cc}, is used in place of F_{cy}. The material determines which nomogram is used to get the critical L/ρ ratio, but regardless of material, the squared parabolic equation and thus Nomogram I, is used for F_c. However, when the L/ρ ratio is small and the column is made from the materials of Nomogram II, this empirical method may yield values of F_c that are too high. Thus a check is made. A limiting F_c value is found using F_{cc} for the column material and Nomogram II. The lower of the two values of F_c is the answer.

Example: A column with a non-tubular cross section is made from 24S-T4 alloy. F_{co} = 48,000 psi, F_{cc} = 30,000 psi, c = 2.0 and L/ρ = 50. Find the maximum load.

Solution: (1) Using F_{cc} = 30,000 and c = 2, Line V on Nomogram II shows $\left(\dfrac{L}{\rho}\right)_{cr} > 100$

(2) Using F_{cc} = 30,000, c = 2.0 and $\dfrac{L}{\rho} = 50$, Line VI in Nomogram I gives F_c = 27,200 psi.

(3) Line VII in Nomogram II shows a limiting value of F_c as 33,900 psi.

(4) Thus F_c = 27,200 psi is the correct value.

Table I—Material Constants for Common Aircraft Aluminum Alloys

Material	F_{cy} Average	F_{co} Values, psi	K	k	n	Type Johnson Equation
14S-T4	34,000	39,800	0.385	3.00	1.0	Straight-line
24S-T3 & T4	40,000	48,000	0.385	3.00	1.0	Straight-line
61S-T6	35,000	41,100	0.385	3.00	1.0	Straight-line
14S-T6	57,000	61,300	0.250	2.00	2.0	Squared Parabolic
75S-T6	69,000	74,200	0.250	2.00	2.0	Squared Parabolic

Ref: ANC-5 dated June 1951

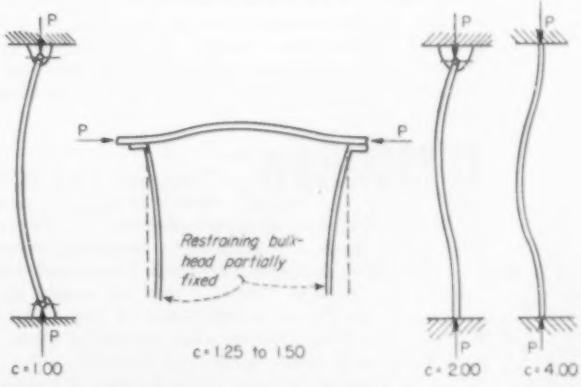

Fig. 1—Values of c, column end fixity, for determining the critical L/ρ ratio of different loading conditions.

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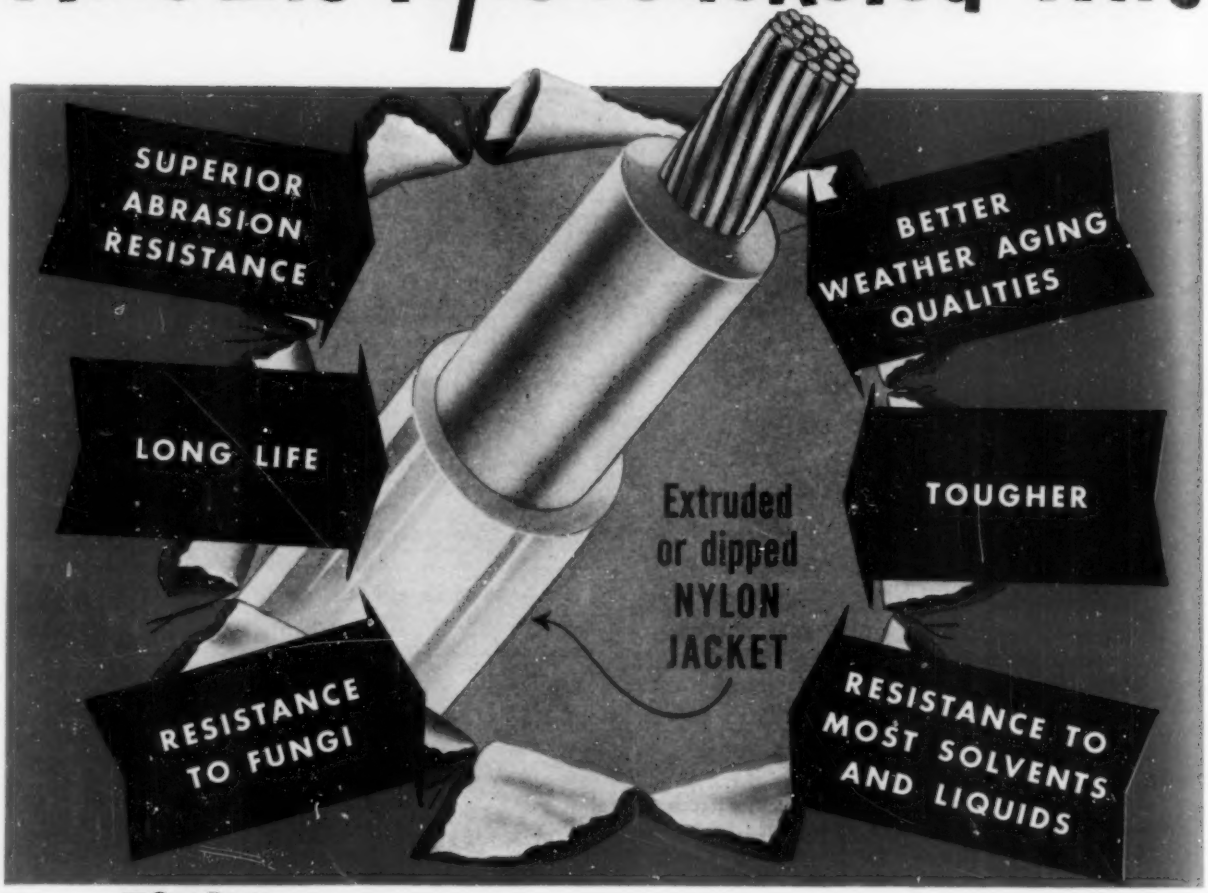

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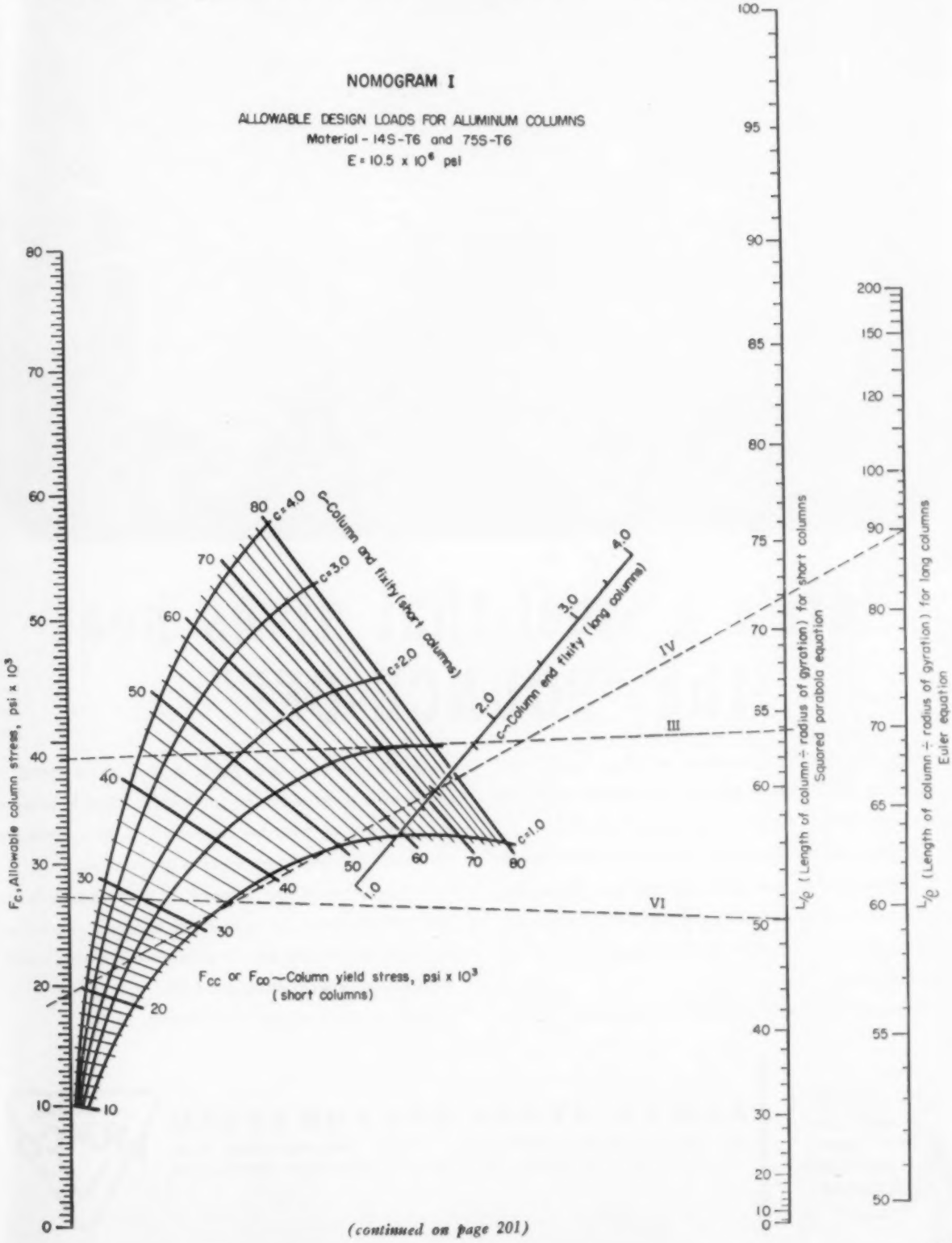
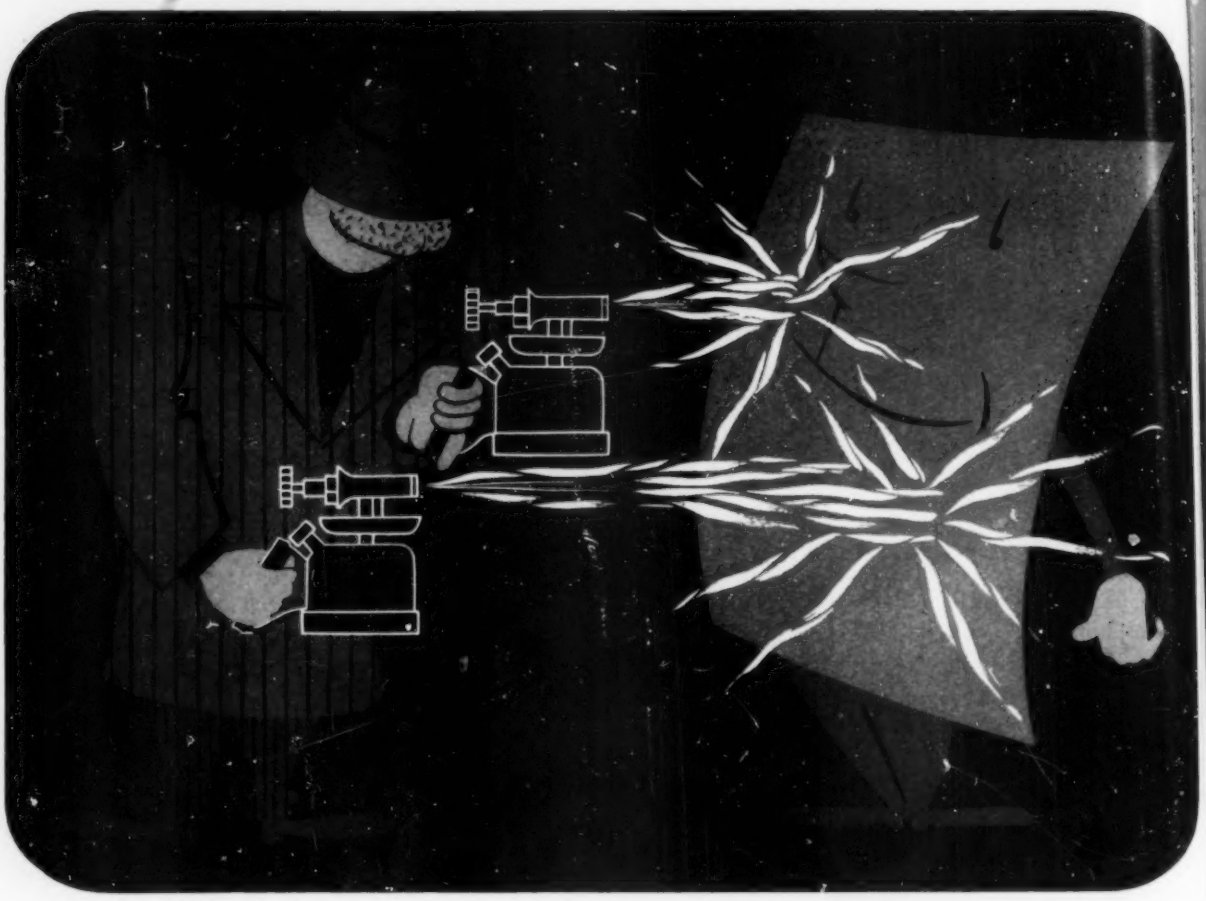
Allowable Design Loads for Aluminum Columns (continued)


NOMOGRAM I
ALLOWABLE DESIGN LOADS FOR ALUMINUM COLUMNS
Material - 14S-T6 and 75S-T6
E = 10.5 x 10⁶ psi
Fc, Allowable column stress, psi x 10³
c=4.0
c=3.0
c=2.0
c=1.0
c-Column end fixity (short columns)
c-Column end fixity (long columns)
Fcc or Fco—Column yield stress, psi x 10³
(short columns)
III
IV
VI
L/ρ (Length of column ÷ radius of gyration) for short columns
Squared parabola equation
L/ρ (Length of column ÷ radius of gyration) for long columns
Euler equation

(continued on page 201)



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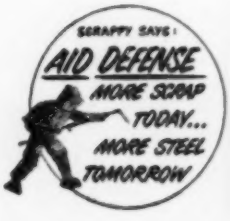

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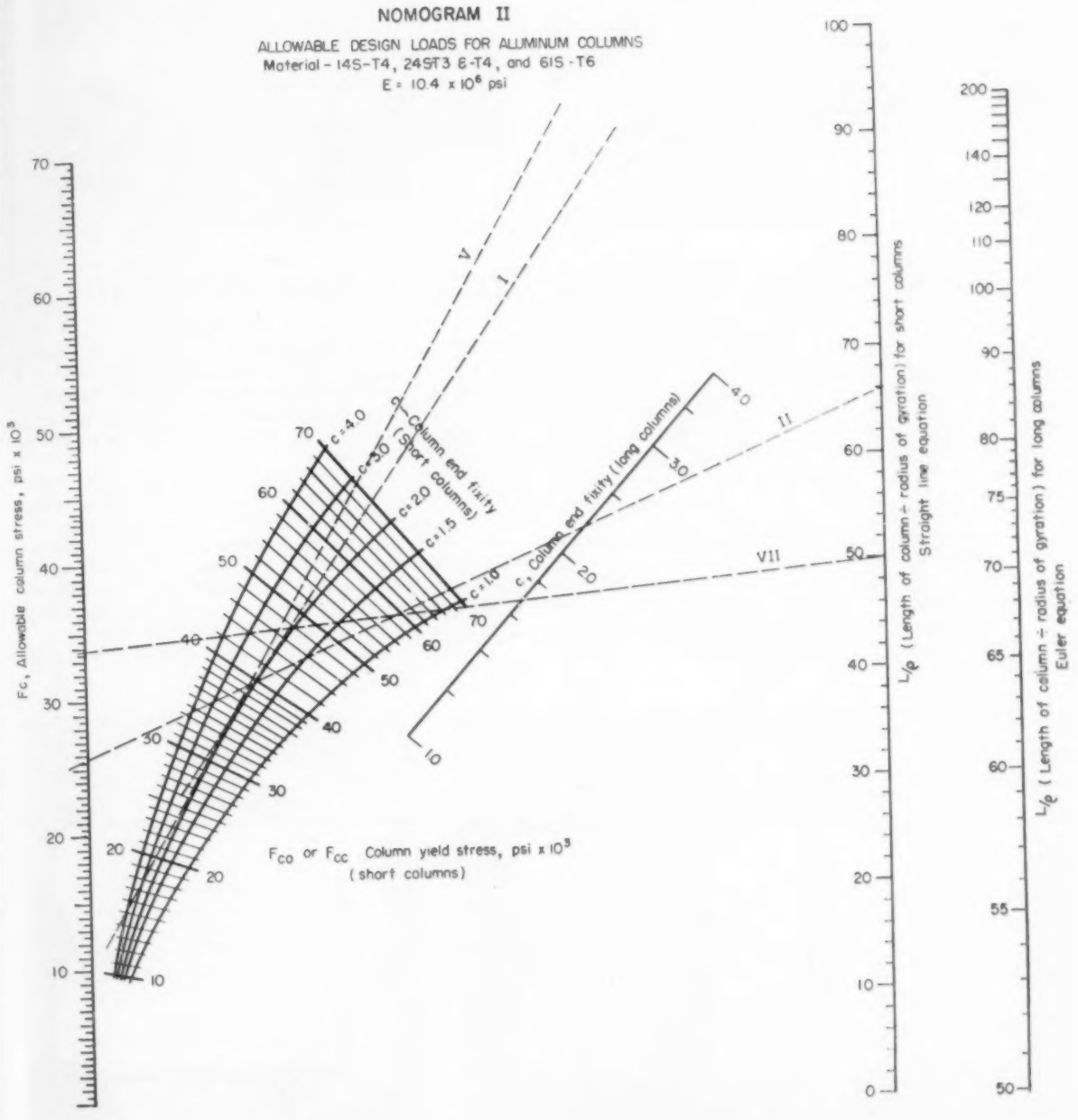
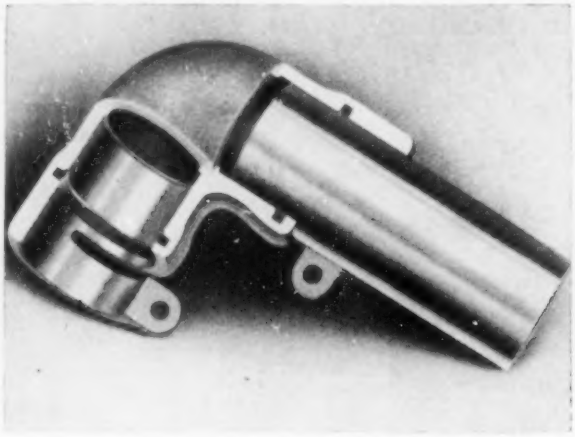
ARMCO

Allowable Design Loads for Aluminum Columns (continued)



NEW COMPONENTS-



Stainless Steel Coupling Reduces Assembly Time

A new stainless steel fitting, known as the quikupl, is a coupling designed to reduce assembly costs by using less expensive, lighter-wall stainless steel tubing. The chief advantage claimed for the new fitting is that it can be joined to the tube or pipe without threading, flaring, sweat-soldering, brazing or welding, thus saving the cost of these operations. With this fitting, the pipe is cut to length, deburred, and inserted in the fitting. The coupling is completed by the tightening of a set screw.

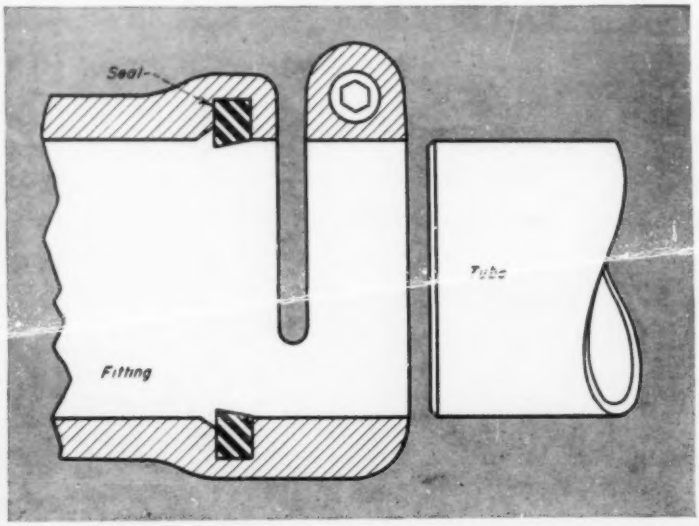
For use at temperatures up to 275 F, depending on the corrosive agent involved, the new fittings are in the 150 psi class. The design also provides for a freer flow, and retards turbulence and pressure drop. Adapters will permit coupling tube lines to existing pipe sizes and fittings.

In appearance the new fittings resemble standard elbows, tees, ells, and other shapes, with the addition of a clamp which is an integral part of the fitting. The only tool required to complete the assembly is a hex wrench to tighten the clamp. Inside the fitting is a synthetic sealing ring which is contained in a groove that is machined into the bore of the fitting.

Other advantages are: reduction of maintenance costs; simplified fitting inventories; it can be used with schedules 5, 10, 40, and 80 pipe sizes without changing fittings.

The new fittings are manufactured in types 304 and 316 stainless, and come in: couplings, tees, 45 deg elbows, 90 deg elbows, and adapters. Tube size fittings available are: 1, 1½, 2, 3½, 4 and 4½ in. O. D.; pipe size tube fittings come in sizes of: 1, 1½, 2, 2½, 3, 3½, and 4 inches.

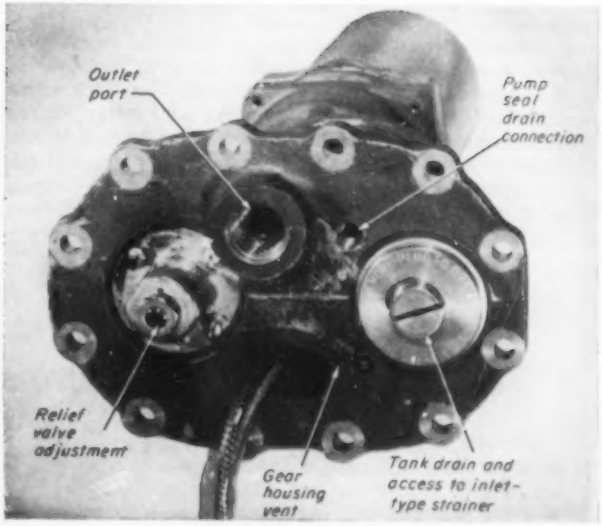
The Cooper Alloy Foundry Co., Hillside 5, New Jersey



Fully Submerged Water Injection Pump

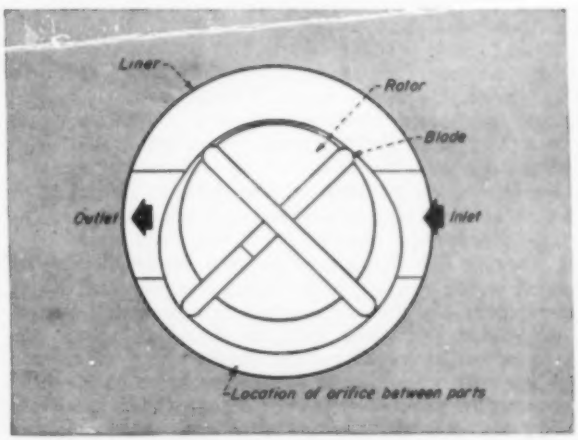
A series of electrically driven, positive displacement, water injection pumps developed for vertically, fully-submerged mounting on the under side of the tank, are used in conjunction with aircraft engine ADI systems (anti-detonant injection). The flush-type mounting flange fits a standard AN4135 oval tank fitting, and is equipped with external relief valve adjustment as well as all fluid and electrical connections.

The adjustable range of the relief valve is 20 to 45 psi; displacement is 0.523 cu. in. per revolution. The unit is rated at 160 gal/hr at 25 psi and 2,800 rpm pump speed, and 9.2 amp at 27 v d-c. It is a ⅓ hp motor, sealed for submersion and explosion proof, with radio interference held below a level of 50 microvolts by a filter. A diaphragm shaft seal on the pump, and an O ring over the gear shaft prevent liquid from entering the reduction gears and motor. The seal is suitable for —65 F operation. Fluid pressure in the seal chamber, between the rotor bearing and the diaphragm seal, is reduced by flow through a bleed hole drilled through the case, which releases to the tank any excess pressure built up behind the seal. A ⅛ in. port is tapped in the mounting flange to drain off seepage from the motor side of the diaphragm.



The pump is of the non-pulsating, rotary vane type. The bore of the liner forms a broad sealing surface at the top, at the point where the radius of the bore and the radius of the rotor have the same center. The close fit of the rotor and liner at the top side of the bore prevents loss of pressure between the high and low pressure sides of the pump. This curvature design prevents movement of the blades in the rotor slots during the sealing and pumping cycles. At the bottom of the bore, or 180 deg from the sealing surface, is the displacement chamber. This has a uniform pumping area throughout, because the space between the rotor and liner does not become smaller at each end before entering the zone of the inlet and outlet ports.

To prevent air from being pumped from an empty tank, two machined slots form an orifice between the inlet and outlet ports of the pump liner, which act as a viscosity controlled fluid by-pass. As the blades pass over these overlapping openings, fluid is displaced. The overlap of the opening acts as an orifice in the presence of air, permitting air to by-pass over the blade ends, and escape to the suction side of the pump.



Galvanic corrosion is eliminated by insulating the pump and other metallic parts of the unit with nonconducting separations, thus preventing antidetonant solution from acting as an electrolyte. Castings and alkalies are anodized aluminum alloy. The pump liner and rotor are monel metal, resistant to most acids, and blades are a carbon-graphite composition which permits dry or wet low-friction running on the monel metal parts. Corrosion resistant finishes are also applied to the stationary parts of the pump to prevent reaction between the water and the metal.

Lear, Inc., Romec Div. Elyria, Ohio

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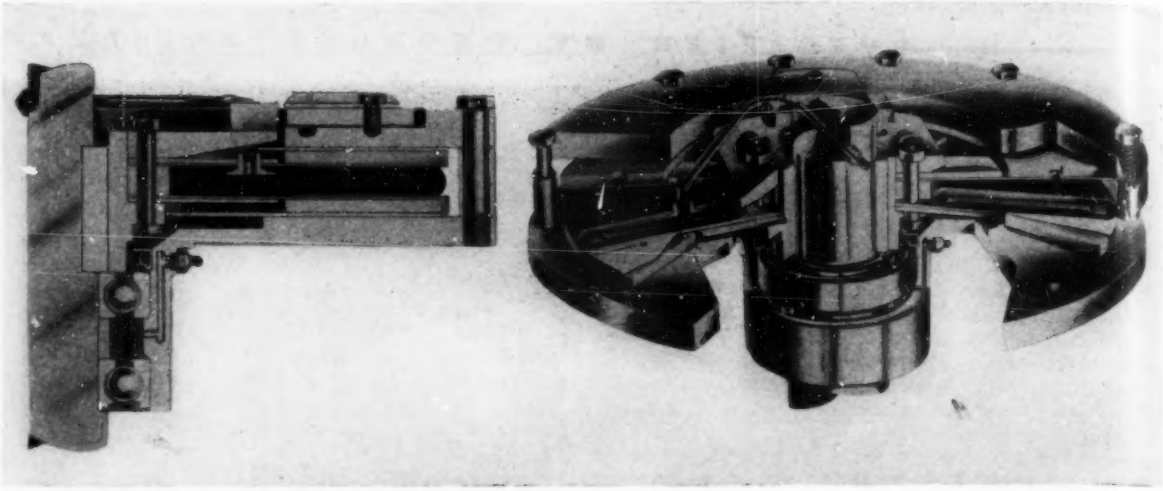


Air Friction Clutch for Heavy Duty Applications

Claimed by its manufacturers to solve the problems of the present day air friction clutches, the new "flex-disk" air friction clutch for heavy-duty applications has such advantages as: no moving parts to wear out; never requires adjustment; will not burn out, clog up or become affected by oil or water; longer friction surface life because of uniform plate pressures and air-cooled operation; and compact, alloy steel construction is said to give light weight and require less shaft space than other air friction clutches.

The clutches are available in single and multiple tube and plate design, and are manufactured in a full range of capacities and sizes to fit every air friction clutch application. Air friction brakes of the same general design, either spring engaged and air released, or air engaged and spring released, are also available.

For more details on the clutch write to the manufacturer.

Cardwell Mfg. Co., Inc., Clutch Div., Wichita, Kansas

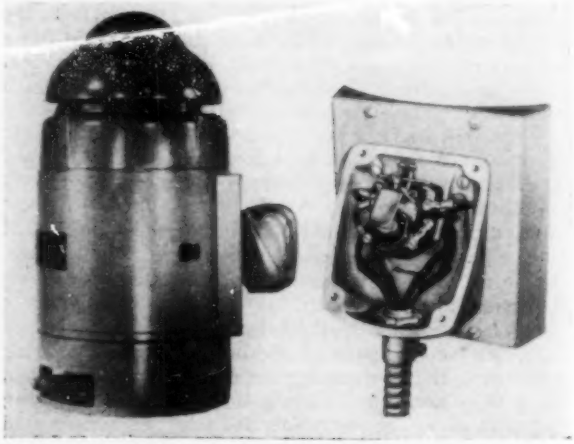
Single Phase Vertical Hollowshaft Motors

Recently added to a line of vertical motors is a series of single phase adjustable hollowshaft motors, types SCU-C, and SCU-R. One of the features of the improvements made on these pump motors is the use of an accelerating type relay to disconnect the starting capacitors.

The relay is located in a split-type outlet box mounted on the outside of the motor. This removes all possibilities of bearing grease working its way into the contact points, or the windstream carrying any dirt into the relay. Because of its location, the relay is easily inspected. Formerly a centrifugal switch, with many moving parts, and critical adjustment was used. The new single phase motor is designed to give maximum performance with positive relay operation over the widest variation in line voltage. Similar to the relays used in hermetically sealed refrigerator units, the large double break contacts give a fast, clean break.

The type SCU-R is a capacitor-start, vertical hollowshaft motor available in ratings of 3 hp or less with dual voltage. The type SCU-C is a single voltage capacitor-start, capacitor-run vertical hollowshaft motor available in 5 hp. Both type motors have speeds of either 1,800 or 3,600 rpm.

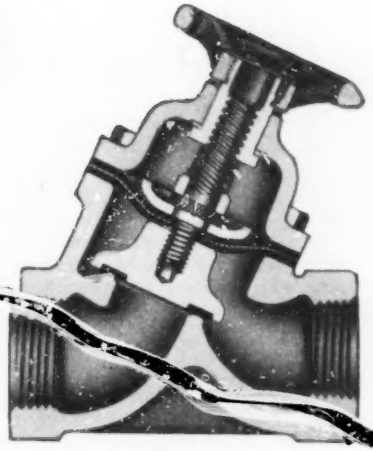
The motors also have a reverse protection clutch which connects the pump shaft to the motor shaft. If, in starting, the motor is accidentally rotated reversely, the pump shaft is automatically disengaged from the motor shaft, preventing the pump shaft from becoming unscrewed by torque reversal, and protecting the pump from any damage.



U. S. Electrical Motors, Inc.
200 E. Slauson Ave., Los Angeles 54, Calif.

CONTINUED ON PAGE 206

For the full piping story...
Turn to your CRANE Catalog



You're never up against a piping problem long when you reach for your Crane Catalog. In this one valuable book you'll not only find an unequaled selection of quality piping materials—but *all* the specification data you need. For each item Crane lists sizes and dimensions, pressure and temperature ratings, and gives complete design, material, and construction details.

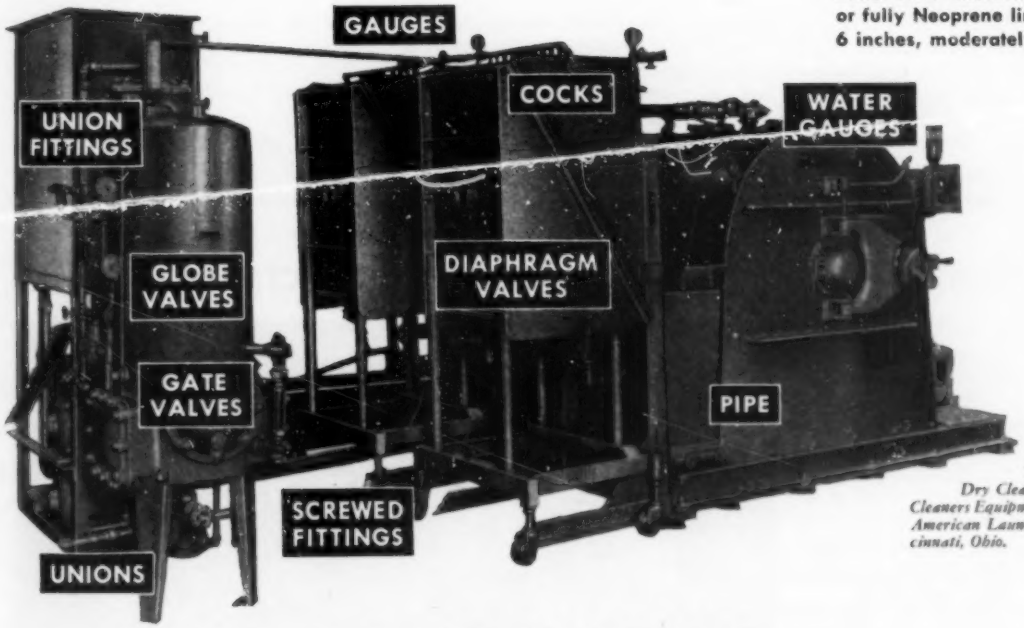
In addition, there's an abundance of general engineering information to help you design better piping systems. And it's all there conveniently arranged and indexed to save you time.

But even more important, when you specify Crane, you know the finished product will be equipped for most efficient flow control. And in times like these when equipment must work harder and last longer, the proved dependability of Crane takes on an importance no machinery buyer can afford to overlook.

FOR BETTER RESULTS

For volatile and hard-to-hold fluids, Crane recommends Iron Body, Y-Pattern Diaphragm Valves. In fact, you can specify this improved "packless" valve for a wide range of services. Note, in Crane design, the diaphragm serves but one purpose—sealing the bonnet. Longer diaphragm service life is assured. The separate disc gives positive shut-off in case of diaphragm failure. Y-Pattern design gives better flow characteristics. Unlined or fully Neoprene lined. Sizes ½ to 6 inches, moderately priced.

YOU'LL FIND THE ANSWER TO BETTER PIPING IN THE BROAD CRANE LINE



Two-Bath TRUCLEEN Dry Cleaning Unit by American Cleaners Equipment Co. A Division of the American Laundry Machinery Co., Cincinnati, Ohio.

The Complete Crane Line Meets All Your Valve Needs. That's Why—

More Crane Valves Are Used Than Any Other Make!

CRANE VALVES

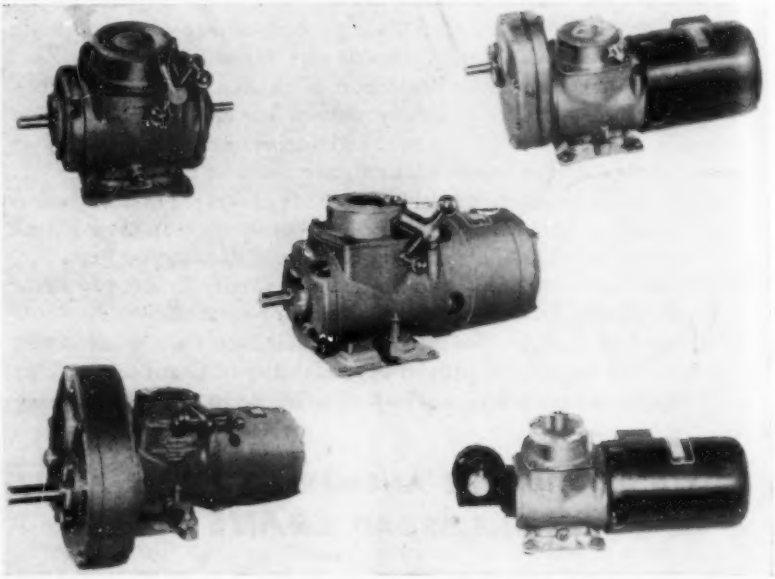
CRANE CO., *General Offices:* 836 S. Michigan Ave., Chicago 5, Illinois
Branches and Wholesalers Serving All Industrial Areas

VALVES • FITTINGS • PIPE • PLUMBING • HEATING

Lighter Powered Variable Speed Transmission

To a line of variable speed transmission has been added a new model designed for operation at 1,800 rpm input without the use of auxiliary spring loading. A lighter powered series, the model 18 gives a wide speed range from any desired maximum to zero with accuracy of speed holding and the ability to reset exactly to a desired speed. Because of its low input speed and absence of spring loading, the transmission has overload protection and in the event of a jam in the driven machine, the transmission can be stalled for extended periods of time without any damage.

The model 18 is available with the many types of controls and reduction assemblies developed for use with the more powerful model 20. In the illustration, the model 18 is shown both with and without motor and with standard output as well as with built-in worm reduction, single stage and double stage helical spur reduction. The control shown is the micrometer control which is furnished as standard with the model 18. One turn of the control handle is made for each of the 40 graduations on the dial. The micrometer handle has 10 graduations permitting the speed to be read accurately to 1/400 of the dial periphery. Single turn, lever, remote mechanical and remote electrical control units in sizes up to 5 hp are available.



The drive consists of the compound planetary gear system, except that the non-rotating member is a traction ring and engages two or more tapered rollers at varying diameters, the ring being moved lengthwise on the transmission to change the speed. The rollers are supported in a carrier, and are inclined at an angle equal to their taper so that their outer edge is maintained parallel to the central axis. The required traction pressure between rollers and ring is obtained through the centrifugal force of the rollers.

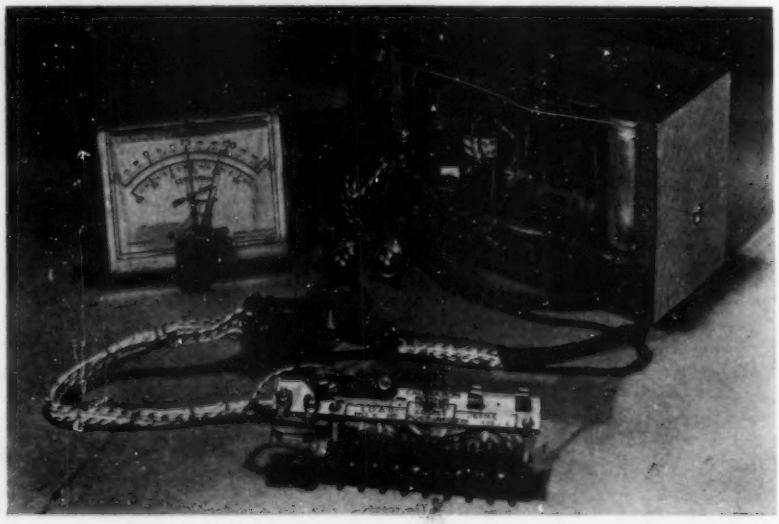
Graham Transmissions Inc., 3754 N. Holton St., Milwaukee 12, Wis.

Complete Automatic Control Assembly

A complete control assembly, for use where only the meter will show on the panel, is made up of the regular simplytrol chassis made by this company, and has hinged mounting brackets so it can be mounted at any convenient location inside the equipment or behind the panel where it is used. A choice of three meter sizes is available: 2½, 3½, and 4½ inches. Called a U-mount-it assembly, this unit is ready made, wired, and tested.

Contact meters indicate and control voltage, current, or temperature. Voltage ranges from 0-5 millivolts to 500 volts; current ranges from 0-20 microamperes to 50 amp; compensated temperature millivoltmeters from minus 200 to plus 3,000 F.

Assembly Products, Inc., Main at Bell Sts., Chagrin Falls, Ohio



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Aid or Trade?
A CRISIS AHEAD

A crisis in the foreign trade relations of the United States is in the offing. It is a crisis caused by:

1. Efforts of producers in friendly nations to earn more dollars by increasing exports to the United States, and
2. Efforts of industries in the United States which would be hurt by competition from these imports to keep them out.

This crisis is a threat to the effectiveness of American leadership in the crucial effort to build the nations of the free world into a strong and unified group. It is the purpose of this editorial to advocate a constructive approach to the difficult situation that is developing.

Background of the Crisis

Most countries in the free world—with American aid—have managed to push their outputs well above prewar levels. As they have done so, they have been urged by our highest government officials to increase their exports to us. Sales in our market enable these countries to earn dollars which they use in turn to buy the products of America's farms and factories. Thus, as they become self-supporting, the need of American aid is reduced.

But as these efforts to export more to the United States have promised increasing success, competitive American producers have become increasingly alarmed about what that success might do to them. Consequently, they are seeking more protection—by appeals to the U. S. Tariff Commission to recommend higher import duties and by appeals to Congress for new laws to discourage imports.

Our Friends Protest

A year ago Congress answered one of these appeals by imposing a quota on imports of dairy products. Now, among many other legislative proposals being strenuously pressed is a move to extend the scope of "Buy American" legislation. A year ago the U. S. Tariff Commission had only four petitions for increased import duties on its docket. Since then fourteen more petitions have been filed and others are definitely on the way.

Faced by these mounting efforts to block the sale of their products in the American market, no less than eleven friendly nations, including Great Britain, France, Italy, Canada, the Netherlands, Switzerland and Denmark, have filed protests with our State Department. Through many of the protests runs one refrain. Although stated in diplomatic language, it might be correctly paraphrased to say: "*In*

sending us aid you have made it very clear that you want us to get on a self-supporting basis at the earliest possible moment. But, when we begin to make headway in that direction by trying to sell you more of the things we are equipped to produce, you start closing your market to us." The threat of European resentment against the United States being stirred up by this argument is obviously great.

At the same time there exist grounds for special resentment in the United States against certain prospective imports of European manufactured goods – those of machine tools, for example. In part these will be produced with machinery that has been sent to Europe as part of our economic aid program. With absolutely no diplomatic language involved, the argument, which will be extended much farther than the facts would justify, will run: *"We gave those people the equipment that they now use to cut our throats!"* This line of argument will find response among workers as well as employers in industries faced by more competition from imports. Labor, too, is keen for protection against more foreign competition.

Aid or Trade?

As between continuing direct economic aid to Europe or accepting the imports that would make those countries self-supporting, some would prefer to continue the aid program. They argue that the tax machinery of the federal government can spread the burden of aid broadly, while we have no comparable machinery that can cushion the shock to individual industries, firms and communities that may result from stepped-up imports of competitive products.

As we see it, this position is untenable. It would make rubbish of our Atlantic Charter promise ". . . to further the enjoyment by all States, great or small, victor or vanquished, of access, on equal terms, to the trade and to the raw materials of the world which are needed for their economic prosperity." It would be an admission that, for all our profession of faith in competition and our opposition to European cartels, we really don't believe in competition.

U. S. Self-Interest

The people of this country have invested billions of dollars and seven years of hard work in the attempt to put our allies on a self-supporting basis. If we keep their goods out by raising trade barriers, we are directly defeating our own purposes.

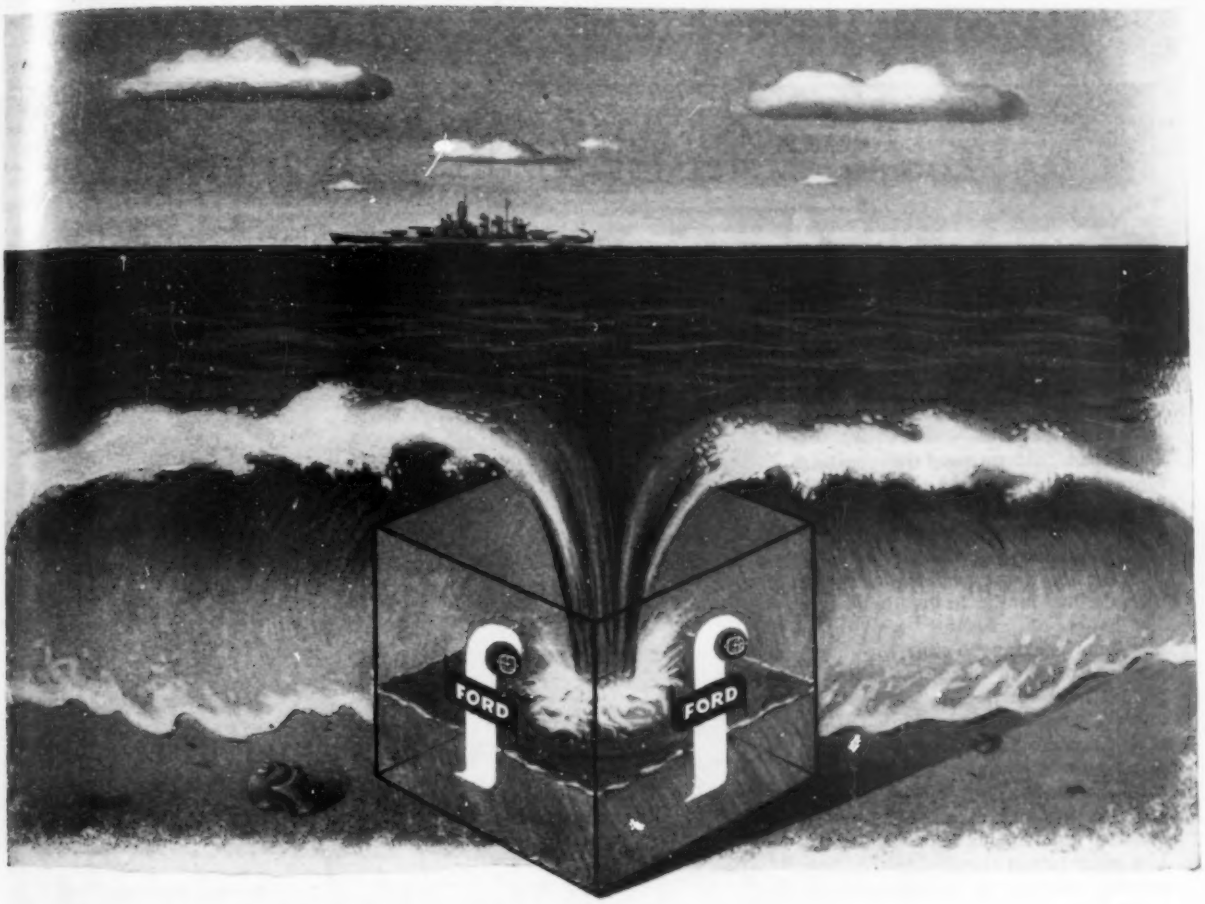
Also, in moving to protect some groups of American producers we should be hurting others. For many American producers the export market, which this year will take about $14 billion of civilian goods, spells the difference between operating at capacity and closing down 25% of their facilities. When we discourage imports we cut off dollar earnings by other nations which are spent here to keep some of our factories and farms going.

At the same time, it must be recognized that certain American industries and their capacity to maintain employment will be hurt by increased imports. Hence it becomes critically important for the United States to formulate a national program designed to help these industries and communities take up the shock.

There is no neat and simple prescription by which this can be done, but several possibilities have been suggested. One on which there is general agreement is that tariff reductions should be gradual. To cushion their impact, the government might well give preference on defense orders to industries and areas adversely affected by an increased volume of imports. Direct assistance to workers and companies in shifting to different lines of business may be worth consideration.

These are by no means all the possibilities. They may not even be the best. But they do serve to suggest the necessity for flexibility and imagination in dealing with the growing crisis in trade relations. *Our ingenuity in developing new ideas to meet this crisis may well be a decisive factor in our effort to weld the free nations into a strong and durable alliance.*

McGraw-Hill Publishing Company, Inc.



We put the ocean in a box...

In addition to the many complex problems solved by Ford for the Military Services there have been less complicated ones such as "bench-testing" a top-classified mechanism by using input signals to simulate the motion of a ship on the open sea. Ford produced these signals within the limited confines of a box.

Whatever the problem in intricate computing devices, no matter how simple or complex, Ford has the engineering "know-how" for its successful solution. For 37 years, Ford has *pioneered* in the field of nationally important automatic equipments with a record of outstanding success.

That is why Ford Instrument Company is usually considered *first* to research, develop, design and produce mechanical, hydraulic, electro-mechanical, and electronic instruments and components for specialized military and industrial applications.

If you are a qualified engineer—either experienced on automatic equipment design or a recent graduate—and are interested in your Tomorrows, consider Ford today. Write for information.

FORD INSTRUMENT COMPANY

DIVISION OF THE SPERRY CORPORATION

31-10 Thomson Ave., Long Island City 1, N. Y.

FORD

Torque Tester for Small Ball-Bearings

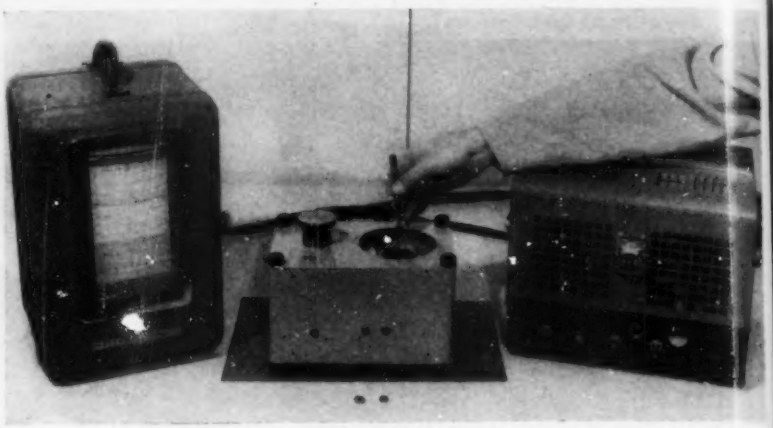
A new device for measuring torque transmitted through small instrument ball-bearings under thrust loads is designed to act as a quality control check in both production line and laboratory work. The new tester is able to show how the torque of a small ball-bearing varies as a function of angular position during a continuous slow rotation in either direction. Basically, the equipment determines the bearing torque by measuring the current drawn by a torque motor in counter balancing the bearing race torque as indicated by an electro-magnetic pickup.

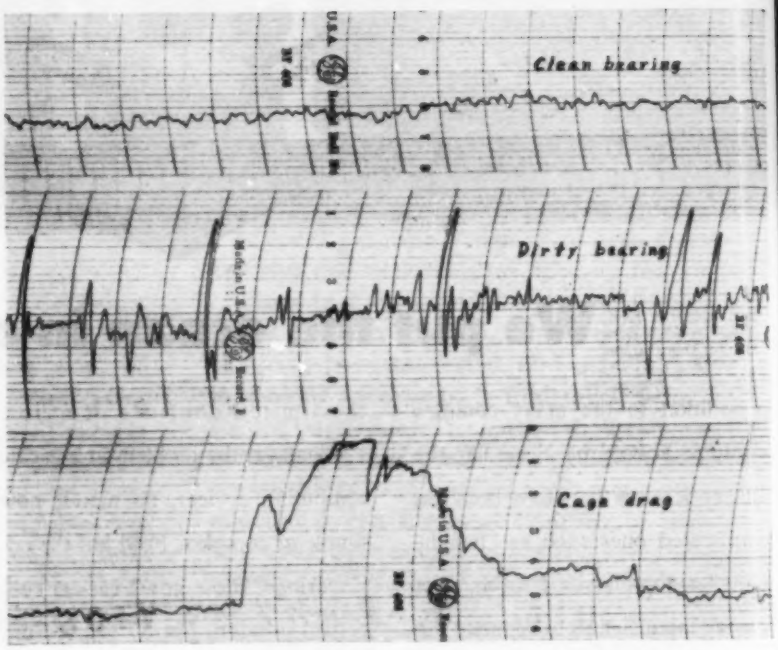
According to the manufacturers, the ball-bearing torque tester will save man-hours of assembly and disassembly by making possible the detection of dirty or defective bearings before their installation in an instrument. The number and height of peaks, average friction, and tendency to bind under load can be determined.

In operation, the bearing to be tested is inserted in an adapter and both are then mounted in the tester. The inner race is clamped to the shaft and the outer race is rotated one revolution by a drive motor.

Torque from the outer race is transmitted through the ball bearings to the inner race and shaft, tending to rotate the shaft assembly and angularly displace an electromagnetic pick-up. A signal, proportional to this displacement, is generated in the pick-up and delivered through an electronic circuit to a torque motor. The motor generates a counterbalancing torque, and, since the two forces tend to equal each other, the motor current is a measurement of the transmitted bearing torque.

With the new tester, complete torque information is obtained in less than two minutes. The data can be either recorded on a recording milliammeter, which will give a complete picture of the torque, or indicated on a microrelay, a "go-no-go" gage.





Designed to accommodate most bearing sizes commonly used in gyroscopic instruments, the mechanical unit is 6 x 9½ x 6 in. and weighs 13½ pounds. The electronic unit is 17 x 8½ x 9½ in. and weighs 21½ lbs, and the recorder is 10 x 13 x 11 in. and weighs 35 pounds. The equipment operates on 115 v, 60 cycles.

General Electric Co., Schenectady 5, N. Y.

A NEW PRECISION 60 CYCLE POWER SUPPLY UNIT, known as the model 375, gives accurate frequency stabilization of five parts per million per degree C for operating test equipment. It gives 60 w of useful power. Input may vary from 50 to 400 cycles, and from 90 to 125 v. Output is constant at 60 cycles, and adjustable from 0 to 150 v.—Ampex Electric Corp., Redwood City, Calif.

A NEW CALENDERED TAPE, having good chemical resistance and dielectric strength, has high oil resistance, making it a natural for use with transformers or diesel equipment. Called Temflex 105, it is not easily stretched but has good ultimate elongation—Irvington Varnish & Insulator Co., 6 Argyle Terrace, Irvington 11, N. J.

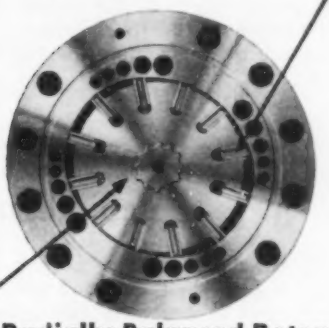
CONTINUED ON PAGE 210

Today's Biggest Value in a Hydraulic Pump or Motor

New Vane Design gives COMPLETE RADIAL BALANCE

"The Finest Money Can Buy!"

Radially Balanced Vanes reduce vane load on the cam ring *regardless of operating pressures.* When system pressures increase, balanced vanes retain low loading characteristics for longer life.



Radially Balanced Rotor. Opposed inlet and outlet porting provides complete radial hydraulic balance of the rotor.

The pumping cartridge, consisting of cam ring, rotor and vanes, operates with complete radially balanced action — assuring less wear on all moving parts.

A Size for Every Need!

Denison's new vane-type PUMP/MOTOR combines *radial hydraulic balance* with *fully interchangeable pump and fluid motor utility* — to bring you the finest that money can buy in compact power ever offered for 2000 psi continuous duty.

Available in four sizes with a choice of cam rings for each size, the Denison HydrOILic PUMP/MOTOR offers eleven different pumping capacities ranging from 2.7 to 70 gpm.

The same units are also *ready to operate* as fluid motors, without alterations of any kind. They offer 11 different torque capacities ranging from 13 to 257 pound-inches per 100 psi.

Think of the Advantages of These PUMP/MOTOR Features!

Balanced Vane Action. Rugged, specially designed vanes contact the cam ring with dual sealing edges. Complete radial balance assures minimum wear.

No Pulsation. Full, radial balance brings uniform delivery that reduces surge and pulsation to a minimum.

Interchangeable cam rings for each PUMP/MOTOR size widens the range of capacities for both pump and motor applications.

Versatility. Each PUMP/MOTOR is ready for use as either pump or fluid motor *without alterations of any kind* — for continuous duty at 2000 psi.

Bi-directional Rotation. All PUMP/MOTOR models instantly adaptable for either clockwise or counterclockwise operation without change or alteration.

DENISON HydrOILics PUMP/MOTOR

The DENISON Engineering Co.
1157 Dublin Rd., Columbus 16, Ohio

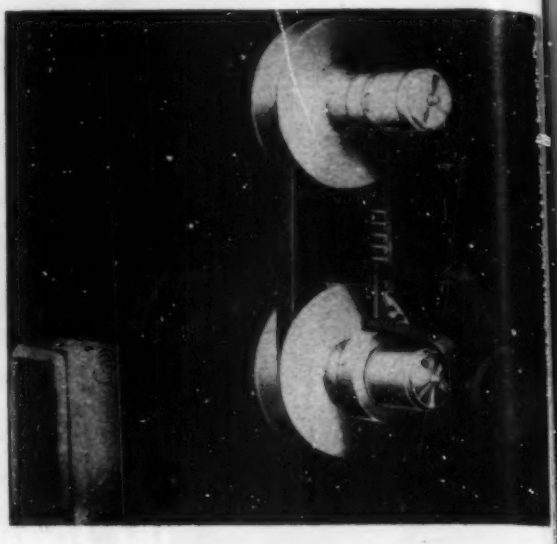
WRITE TODAY FOR
PUMP/MOTOR Bulletin No. P-5

Variable Speed Pulley on Fixed Centers

Designed for power applications requiring maximum speed variation, the new roto-cone manually operated variable pitch motor pulley, used in combination with a standard roto-cone variable pitch pulley and a standard varispeed belt, permits a speed-change ratio up to 9 to 1.

Speed change is accomplished by adjustment of the manually operated pulley. The ball bearing mounted retainer ring on the pulley hub contains two studs to which the adjustment mechanism is attached. As the pulley rotates, the retainer ring is stationary and through lateral inward and outward movement of the adjusting member, the pulley changes pitch diameter. Because both the manual and self-adjusting roto-cone are on fixed centers, and the belt length remains constant, variation of one pulley automatically affects the other inversely.

The U shaped yoke, large enough to clear the grease fitting when attached to the retainer ring studs, is recommended as the primary piece of the control mechanism. A torque arm attached to the yoke, should be made to prevent the yoke and bearing retainer from rotating.



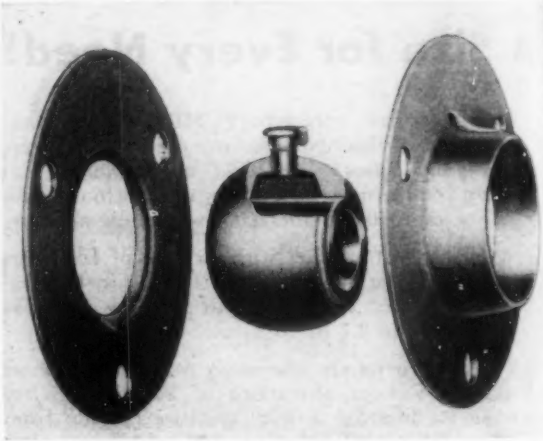
Gerbing Mfg. Corp., Northbrook, Illinois

Self-Aligning Sleeve Bearing Unit

This compact, self-aligning, sleeve bearing unit, especially designed for light shaft duty and power take off application on all types of sheet metal fabrications, has for some of its applications: textile machinery; air moving equipment; packaging machinery; conveyors; and agricultural implements.

The flange mounting is made of 16 gage steel which is press-shaped to match the spherical shape of the ball assembly. The two flange mountings are then bolted together, holding the ball assembly inside. The ball assembly is a machined cast-iron hollow ball in which an oil reservoir is formed when the bushing is pressed into place. The reservoir is packed with SAE No. F-11 wool felt which becomes saturated with oil as the reservoir is filled. Oil is fed to the bearing surface by the capillary action of the sintered bushing, or the graphited bushing, whichever is required. Heat increases the capillary action, giving a self-lubricating feature.

The bearing assembly measures 3½ in. dia. by 1¼ in., and is available with sintered bushing for shaft sizes ½ in., ⅝ in., ¾ in., 1⅛ in., and 1 in., and with graphited bushings.



Randall Graphite Bearings, Inc.
1011 S. Greenlawn Ave., Lima, Ohio

Miniature "Building Block" Electronic Circuits

A small number of basic electronic circuits have been assembled in a building block fashion to form an electronic digital computer and other complex devices to make possible the testing of new ideas without using a series of calculations and experiments, or of complicated circuits.

These small circuits, 1 7/16 x ⅝ x 2⅛ in., are light in weight, with the heaviest circuit, complete weighing only 1½ ounces. These units plug into assembly boards.

The small size of these circuits is made possible by the use of sub-miniature vacuum tubes, handwound coils and special hand made transformers. The circuits include bi-stable multivibrators (flip-flops); astable multivibrators; monostable (or delay) multivibrators; delay lines; pulse amplifiers; cathode followers; and gates.

The Jacobs Instrument Co., Bethesda, Md.

CONTINUED ON PAGE 212

MAKE A TON OF SHEET STEEL GO FARTHER
Specify—
N·A·X
HIGH-TENSILE STEEL
... And "MAKE YOUR PRODUCT LAST LONGER"

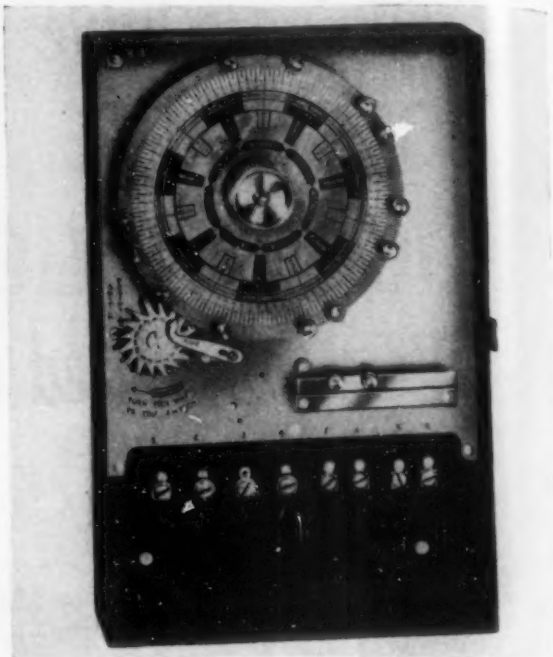
Containers and pressure vessels assure greater service when made of N-A-X HIGH-TENSILE steel. The durability of this low-alloy steel, its greater resistance to corrosion and abrasion, and its exceptional fabricating and welding qualities are important characteristics. The greater strength of N-A-X HIGH-TENSILE steel permits fabrication of containers from thinner sections—reducing costly deadweight to a minimum. If you are interested in effecting economies in barrels, drums or cylinders, investigate N-A-X HIGH-TENSILE steel.

GREAT LAKES STEEL CORPORATION

N-A-X Alloy Division — Ecorse, Detroit 29, Mich.

NATIONAL STEEL CORPORATION

Seven-Day Calendar Dial Time Switches



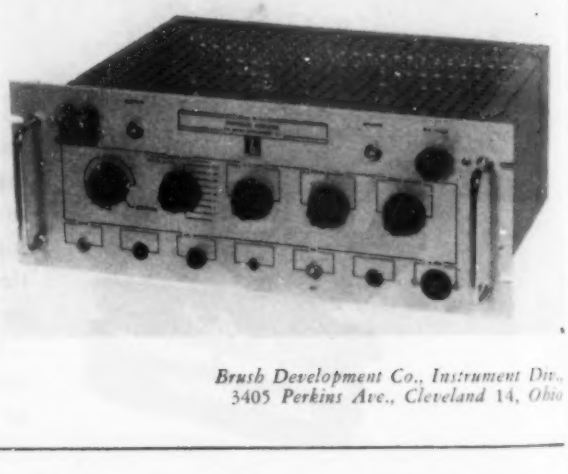
Fitted with 6 in. calendar dials which make one complete revolution every 7 days, the 700 series time switch separates each day of the week, graduates hours and half hours, and separates the day and night periods. This makes it easy to locate the operating riders, 14 of which are supplied as standard equipment, to control operations at the selected time.

With this unit, heating, ventilating, lighting, pumping, flushing systems, or any electrically controlled operations can be turned on and off automatically at different hours each day if necessary; or any day or days can be omitted entirely. Settings can be made in advance for one week, and are adjustable throughout each 24-hour day. Dial settings on the switches show how heat may be cut down on Saturday noon, and started again on Monday through settings advanced to compensate for week-end shutdowns. Flexibility of operations is the feature of the 700 series time switch. Operations from on to off, or from off to on can be accurately set as close as three hours apart. The switches in this series are available in 24, 115, and 230 volts; and 25, 50, and 60 cycles.

The 9624 series time switch is designed for 24 hour control and has a dial graduated in 15 min. increments. It can be set for as many as 48 "on and off" operations of 15 minutes each during the 24 hour day.

Paragon Electric Co., Two Rivers, Wisconsin

Carrier Type Amplifier For Rack Mounting



Designated as model BL-360, this carrier type amplifier was designed for use in a standard 19 in. rack, and having a 7 in. front panel. The instrument is used with the magnetic direct writing oscillographs, also made by this company, in studies of static or dynamic strains up to 100 cps when measured by resistance sensitive strain gages. Pressures, temperatures, torque, accelerations, and forces may be recorded with the correct pickup device.

The model BL-360 was designed for use with the SR-4 120 ohm strain gage, but may be used with any gage type with ohmic resistance of 50 to 1,000 ohms. Provision is made for operating one to four active gages. The measurable range of the instrument is 10 to 40,000 microinches per in. with one active gage.

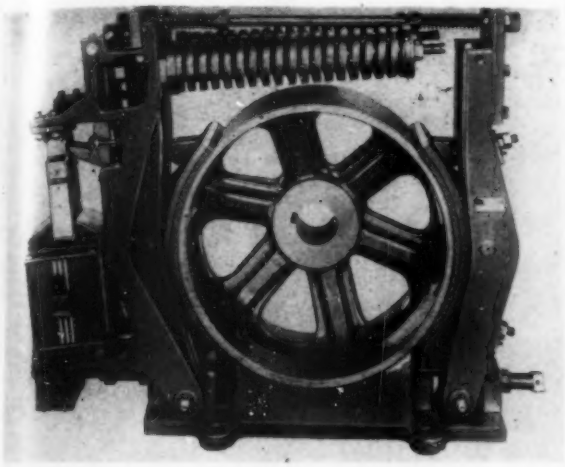
The control panel of the BL-360 amplifier has: a ten stop attenuator, terminals for connection of strain gages, calibration resistor holder, resistance and capacity bridge balance controls, gain controls, and pen centering control.

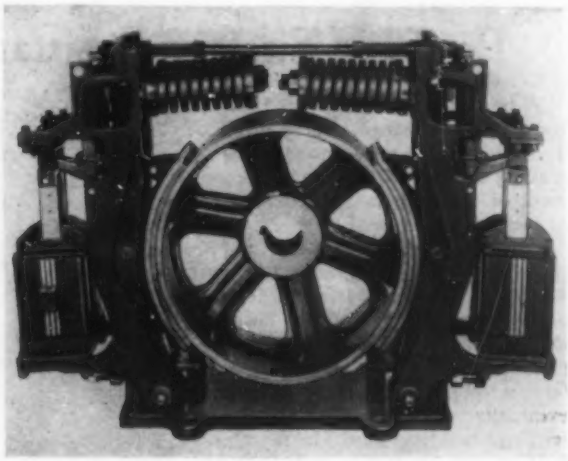
Brush Development Co., Instrument Div., 3405 Perkins Ave., Cleveland 14, Ohio

A PENETRANT DYE INSPECTION PROCESS detects cracks, pores and cold shuts, often microscopic in size, in all types of metal parts. Process may be used in all ferrous, non-ferrous, ceramics, glass, and thermosetting plastic parts. Process involves only two solutions.—Met-L-Check Co., 121 N. Prairie Ave., Hawthorne, Calif.

THE FEATURE OF A NEW TYPE DRIVING TAPE is the hinged center which creates much greater lateral and longitudinal flexibility. Used for driving spindles on spinning frames and twisters, this tape, called the "overdrive," follows accurately the contour of the whorl. The driving effort of the tape is transmitted with a low percentage of slip.—Lambeth Rope Corp., New Bedford, Mass.

CONTINUED ON PAGE 215





Solenoid Operated Shoe Brakes

A new design in solenoid operated shoe brakes is shown in the illustration at the top. In its complete and standard form it consists of four sets of springs, two solenoids, and one torque tie bolt connecting two practically independent operating units, one for each brake shoe. Each unit is composed of a set of auxiliary arms and a set of shoe supporting arms, pivoting on the same fulcrum on top of the mounting base. The position on each of the two fulcra can be changed by set screws, making it possible to move the whole brake a certain distance to one side or the other in order to bring the center line of the brake to coincide with the center line of the brake wheel or shaft of the motor, and getting, if necessary, precision alignment with the motor after the brake has been mounted on the floor.

The brake shoes are mounted on shoe supporting arms by a ball and socket pin, making it possible for them to adjust themselves to the wheel. Each brake shoe has two anti-toeing devices to completely eliminate the toeing difficulties usually found in shoe brakes.

The moveable fulcra of the two units makes it possible to adjust for wear, both at the bottom and at the top of the mechanism.

Four sets of springs, each set consisting of a nest of at least two springs, one inside the other, give the brake a flat spring characteristic. For the same reason, to adjust the torque from zero to full value, it requires the turning of four nuts making an aggregate length of thread varying anywhere from 2 to 10 inches, depending upon the size of the brake; thus giving a fine torque adjustment.

The brakes are operated by long stroke solenoids, and as a rule, about 40 to 50 percent of the stroke is used to release the brake, and 50 to 60 percent of the stroke is available for wear of the lining. This makes the period between adjustments for wear very long. Solenoid operated shoe brakes can be obtained for capacities as high as 24,000 ft-lb continuous duty to operate on any voltage and frequency. With d-c, brakes are made for shunt or series operation.

Each unit has a hand release, and is capable of releasing the brake by itself, so that one of the solenoids may be used as a spare, allowing the other solenoid to release the brake in actual operation. Brakes made this way are supplied with a dummy weight to be used when a solenoid has been removed for repairs. The dummy weight keeps the brake statically balanced, and permits continued operation.

When it is necessary to get a small distance between the center line of the shaft and one end of the brake, the brake can be made with one solenoid only, as is shown in the illustration at left. All other qualities of the brake are the same. Static balance is obtained by the use of a spring underneath the solenoid to neutralize the unbalanced moments. The solenoid will also have two sets of springs instead of four.

The brakes are available for the following operation: a-c operated and holding; a-c operated, d-c holding, with the releasing done by an a-c solenoid; d-c operated, and d-c holding. The latter type brake may be operated either on direct current circuits or on alternating current circuits by use of a rectifier.

Trombetta Solenoid Corp.,
329 N. Milwaukee St., Milwaukee 2, Wis.

PRECISION MOLDED, SNAP-ON MASKS of synthetic rubber are now used to cover surfaces or parts that must remain bare after plating or painting. This eliminates the process of coating by wax or lacquer, and cutting away the coating later. The new device saves time, and may be used indefinitely.—Duggan Masking Devices, 2030 W. Fort St., Detroit, Mich.

SUITABLE FOR OPERATING TEMPERATURES of —60 to +120 C, a new insulating compound designated as HLT 500 shows little effect on electrical and physical properties when aged for 7 days at 150 C. Used on transformer leads, motor leads, coil and relay leads, and in areas where temperature build-up is excessive.—Chester Cable Corp., 521 Fifth Ave., Chester, N. Y.

CONTINUED ON PAGE 216

Seven-Day Calendar Dial Time Switches

Fitted with 6 in. calendar dials which make one complete revolution every 7 days, the 700 series time switch separates each day of the week, gradu
and separates the day and night p
to locate the operating riders, 14
standard equipment, to control
time.

With this unit, heating, ventil
flushing systems, or any electrica
can be turned on and off automa
each day if necessary; or any day
entirely. Settings can be made i
and are adjustable throughout eac
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Saturday noon, and started again
tings advanced to compensate f
Flexibility of operations is the f
time switch. Operations from on
can be accurately set as close as
switches in this series are availab
volts; and 25, 50, and 60 cycles.

The 9624 series time switch i
control and has a dial graduated ir
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Paragon Electric C

Carrier T

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The model BL-360 was designed
120 ohm strain gage, but may be us
with ohmic resistance of 50 to 1,0
made for operating one to four acti
able range of the instrument is 10
per in. with one active gage.

The control panel of the BL-360 a
attenuator, terminals for connecti
calibration resistor holder, resistanc
balance controls, gain controls, and

A PENETRANT DYE INSPECTIO
PROCESS detects cracks, pores and col
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be used in all ferrous, non-ferrous
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Corp., New Bedford, Mass.

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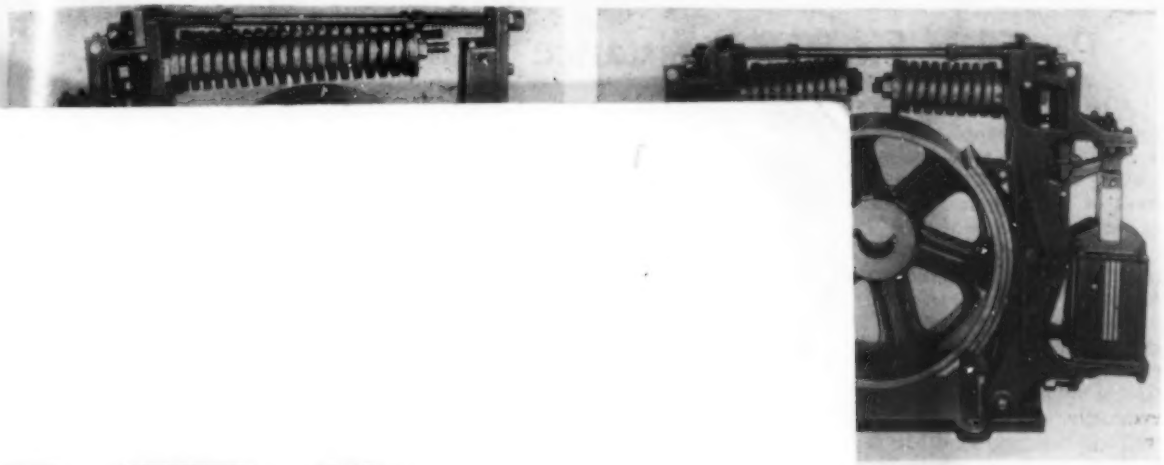

AGES

SSING

kes

to 60 percent of the stroke is lining. This makes the period ear very long. Solenoid oper- tained for capacities as high as uty to operate on any voltage brakes are made for shunt or

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Trombetta Solenoid Corp., Milwaukee St., Milwaukee 2, Wis.

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main bare after plating or painting. This eliminates the process of coating by wax or lacquer, and cutting away the coating later. The new device

SUITABLE FOR OPERATING TEMPERATURES of —60 to +120 C, a new insulating compound designated as HLT

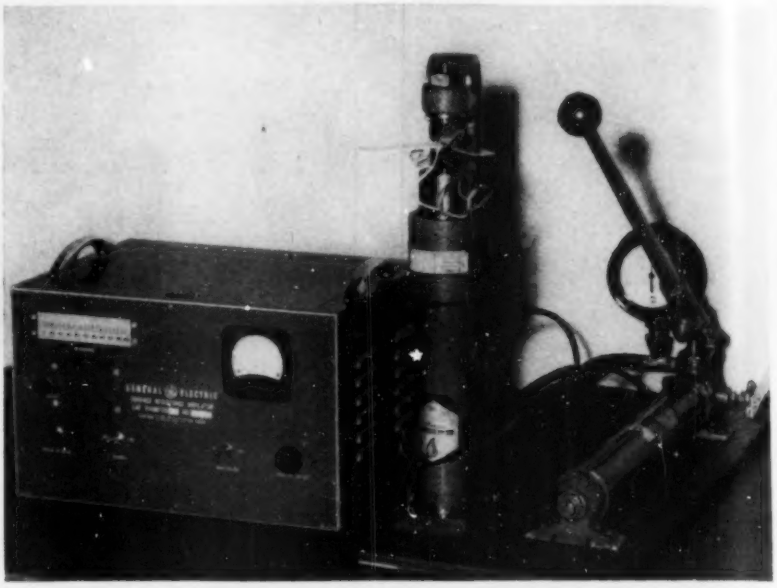
—CONTINUED ON PAGE 216

Portable Surface-Resistance Indicator

A portable surface-resistance indicator has been designed to help produce a better resistance welding bond by making a rapid and accurate measurement of the resistance between pieces of metal to be welded.

The new device supplies a simple check on pre-welding cleaning processes, upon which the surface resistance of the metal depends. Small changes in concentration or slight contamination of cleaning solutions cause surface resistance to vary widely, and eventually result in an unsatisfactory resistance welding bond. In resistance welding aluminum, electrode pickup, inconsistency in welds, and the forcing out of the metal can be reduced if the surface resistance of the metal is known before welding.

The new equipment comprises two parts: a microhmmeter and a sample holder. The sample holder consists of an hydraulic ram which has a pair of current electrodes, emf electrodes, and a pressure gage. The emf electrodes are spaced to make the measurement independent of sample size.



In operation, the sample pieces of metal to be welded are placed between the jaws of the sample holder and subjected to the desired pressure. The surface resistance between the metal samples is indicated on the microhmmeter, which is connected electrically through an extension cable to the sample holder.

The unit has two ranges: 0-200 and 0-2000 microhms. The measured resistance is indicated directly in microhms on a linear 100 division scale. Voltage fluctuations in the supply mains do not affect the reading.

The microhmmeter is 9½ x 15 x 11 in., and weighs 23 pounds. The sample holder weighs about 30 lb, has a clamp throat depth measuring 3 in., an electrode clearance of 2 in., electrode surface radius of 4 in., and an electrode diameter of ⅝ inches.

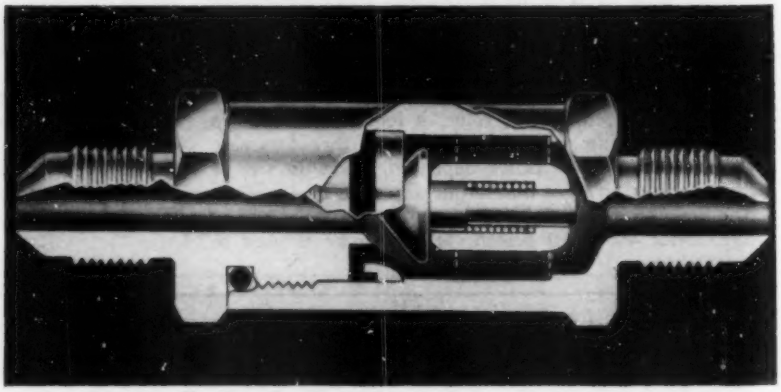
General Electric Co., Schenectady 5, N. Y.

Air Check Valve with Minimum Pressure Drop

A new air check valve, designed specifically for aircraft pneumatic service, will not leak at any pressure up to 4,500 psi. The streamlined poppet, and the straight through flow of air give a high flow capacity with minimum pressure drop.

The rubber seat is positively positioned and retained to prevent wash out during high surge flow conditions. It meets the surge flow test requirements of specification MIL-V-5524A for hydraulic check valves using hydraulic fluid conforming to specification MIL-O-5606.

The rubber seat is not affected by MIL-O-6085 (formerly AN-O-11) and MIL-O-6081 (formerly AN-O-9) oils.



Because of the large seating area, the valve performance is not affected by dirt particles, or ice formation on the seat. The poppet spring is not exposed to, or affected by the air.

The valve is available in both aluminum and stainless steel. Minimum weight for aluminum is 0.07 lb; for stainless steel, 0.16 pound.

The Cornelius Co., Minneapolis 1, Minn.

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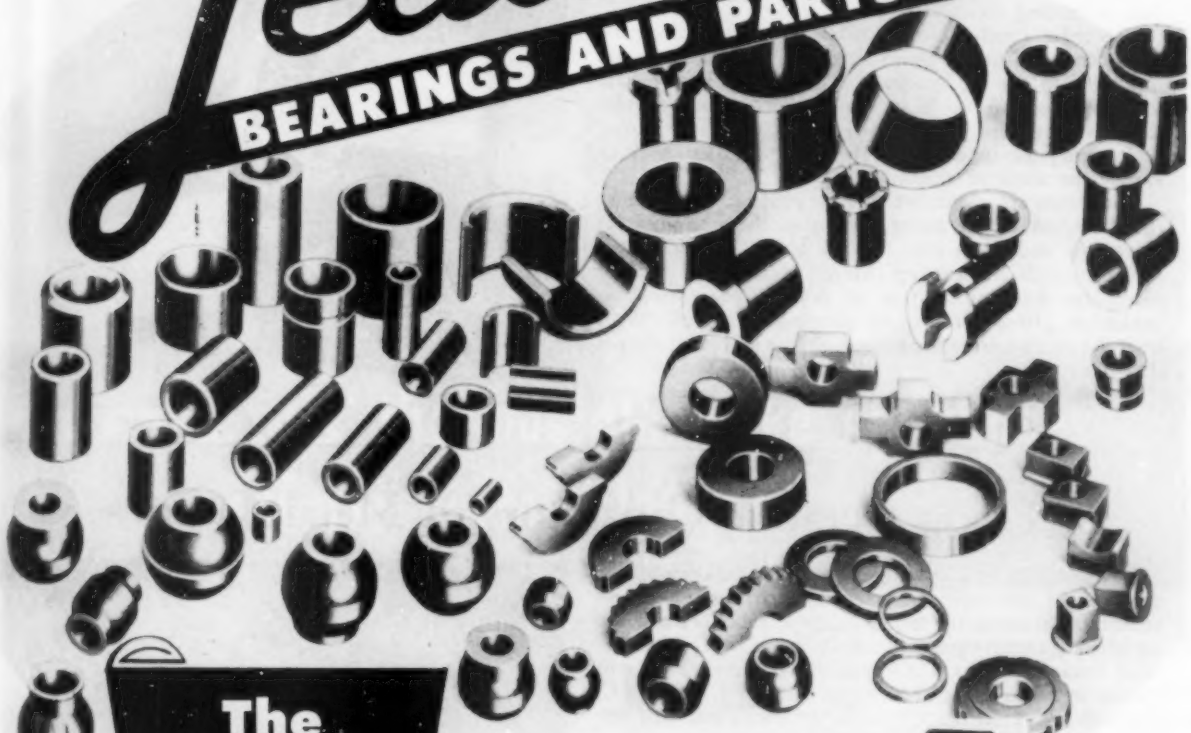
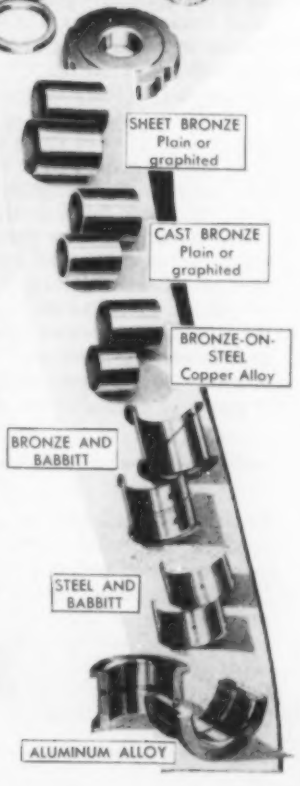
JOHNSON Ledaloyl
BEARINGS AND PARTS



The Answer to Lower Costs

SHOULD your application be difficult or impossible to lubricate, where excess oil may damage the product, where lubrication might be neglected, one where heavy duty service is not a factor, or one requiring self-alignment . . . investigate the advantages of Ledaloyl Bearings and Parts. New uses are being discovered continually. In each application you can make substantial savings. Ledaloyl Bearings and Parts are extremely low in cost because they are produced by powder metallurgy, molded to shape, and require no machining. They are impregnated with oil and in service become self-lubricating. In many applications they give the utmost in service. Johnson Engineers will gladly help you determine whether you should use Ledaloyl bearings. Write for appointment.

JOHNSON BRONZE CO. 508 South Mill St., New Castle, Pa.



SEND FOR DATA SHEETS GIVING PROPERTIES OF LEDALOYL

●

SLEEVE BEARING HEADQUARTERS SINCE 1901

JOHNSON B BEARINGS
Sleeve-Type

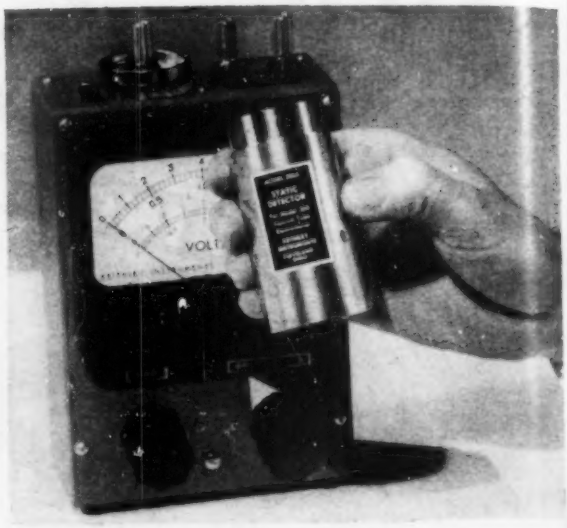
Static Detecting Device Used With Electrometer

Called the model 2005 static detector, this device clips onto the vacuum tube electrometer, also made by this company, and makes a convenient combination for detecting and locating static charges. The detector prevents high static potentials from overloading the instrument, and also aids in locating the charge.

The static detector consists primarily of two concentric tubes connected to the guard ring, and an aluminum rod connected to the HI terminals. The tubes shield the HI terminal electrode so that charges along the cylinder axis have the most effect. Sensitivity is varied by raising or lowering the inner tube. This acts to either cover or expose the sensitive aluminum rod.

The results are qualitative, and are observed by watching the deflection of the meter pointer as the instrument is moved to and from the charged object. It is useful in textile mills for locating charged bobbins; in printing plants for detecting charges on moving paper; and in explosives plants for sensing dangerous charges. With the tube on the detector lowered, a charged comb throws the pointer off of the scale from a distance of 10 feet.

Keithley Instruments, 3868 Carnegie Ave., Cleveland 15, Ohio

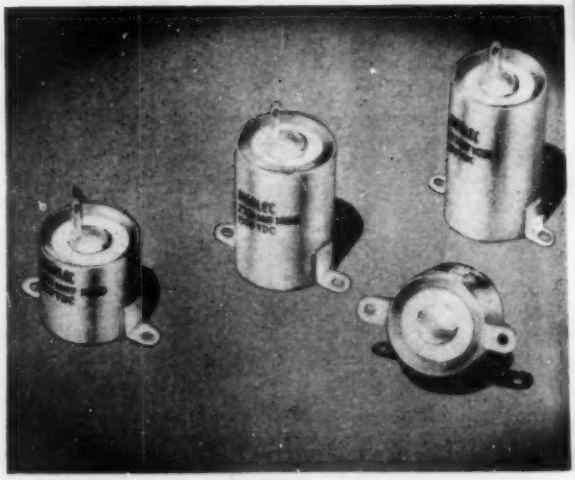


Precision Ceramic Capacitors in Metal Tubes

Developed especially for use in high stability oscillator circuits, and electronic instrumentation circuits, these new capacitors, hermetically sealed in metal tubes, extend the capacitance range of close-accuracy ceramic capacitors at rated voltages of 500, 1,000, and 1,500 v d-c. They will operate over the temperature range of —55 C to +85 C, and will withstand the vibration and shock normally encountered in military electronic gear.

The basic construction of the B20, B21, B22, and B23 capacitors consists of stacks of ceremic dielectric disks with silver electrodes fired on at a high temperature. The stacks are thoroughly impregnated and hermetically sealed in 1 in. dia. plated metal shells.

The stability of these precision capacitors makes it possible to control capacitance tolerances and temperature coefficient tolerances within close limits. Where these capacitors are used in precision circuits, it is often possible to control the capacitance tolerance within plus or minus one percent, and temperature coefficient for less critical circuits is plus or minus 30 parts per million per deg centigrade, or plus or minus 15 percent of the nominal temperature coefficient.

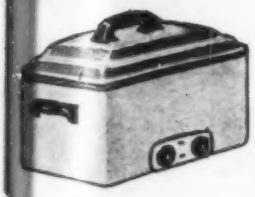


Sprague Electric Co., 195 Marshall St., North Adams, Mass.

EIGHT NEW MODELS in a line of standard electronic power supplies have been developed varying in rating from 100 milliamp up to 500 milliamp, and from 200 v up to 1,000 volts. Some have bias voltage ratings either at 0 to 150 v, or 0 to 300 v at 5 milliamp. Each model also has a filament output voltage at 6.3 v at either 3, 6, or 10 amps. Used as a 19 in. rack panel or a cabinet type assembly—Perkin Engineering Corp., 318 Kansas St., El Segundo, Calif.

A COMPLETE LINE OF SUB-MINIATURE TUBE SOCKETS has been designed for high efficiency in electronic equipment where space is at a premium. They are mounted without screws or rivets. The new material used for the socket is an injection molded glass-bonded mica for the socket body, and is rated as a grade L-4B insulation. Low loss factor of 0.015 at 1 mc; insulation resistance min. 50,000 megohms.—Mycalex Tube Socket Corp., 30 Rockefeller Plaza, New York 20, N. Y.

—CONTINUED ON PAGE 220



ROASTERS

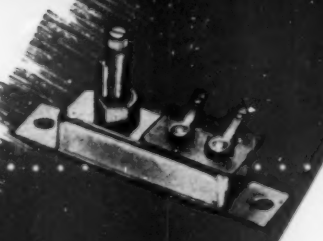
TYPE R thermostats give clean, positive make and break of circuit. Also used in range warming compartments, low-wattage water heaters, and electronic devices requiring a high degree of temperature control.

IRONS

TYPE S thermostats feature clean, positive make and break. Electrically independent bimetal prevents artificial cycling for longer thermostat life. Available in adjustable and non-adjustable styles precalibrated for your product.

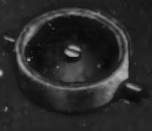
STEVENS

STEVENS thermostats make appliances perform better—longer



REFRIGERATORS

TYPE W thermostats give *snap-action* make or break on temperature rise. Used widely in butter-warming compartments, electronic devices, rectifier fans, and apparatus requiring sensitive, precise control of high-wattage heater loads.



PERCOLATORS

TYPE M thermostats have bimetal disc that gives *quick* make and break in appliance, apparatus and electronic applications where close control and compactness are essential. Open, hermetically sealed, or neoprene-protected styles for severe dampness.

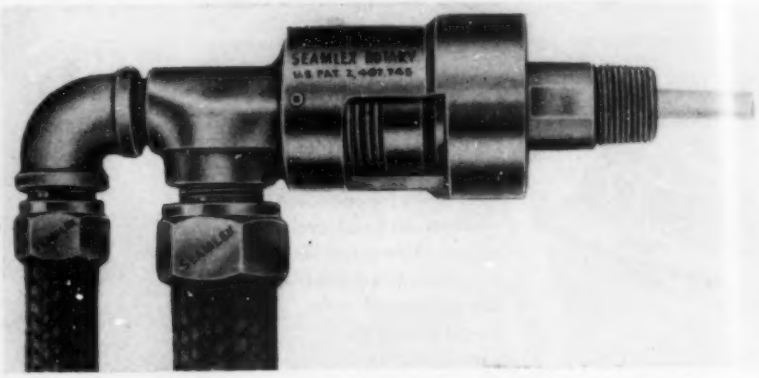
STEVENS

Stevens makes the largest line of bimetal thermostats in the industry—several hundred styles in all. So even if you have an unusual design problem, check with Stevens first. Probably a standard Stevens thermostat will fill the bill for specifications, price and delivery—and at the same time insure the performance and life of your product. A 6611

STEVENS

manufacturing company, inc. MANSFIELD, OHIO

Self-Aligning Rotary Pressure Joint



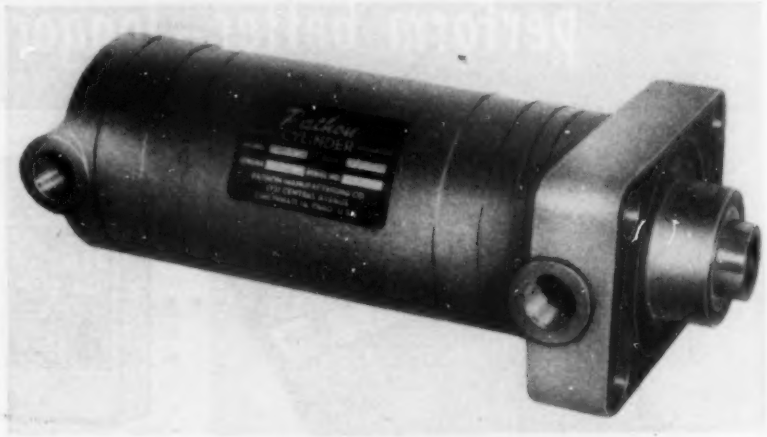
The standard class 15 capacity of the new rotary joint shown in the illustration is 150 psi, 350 rpm, at 350 F, and is designed to carry liquids and gases from a stationary pipe line to any revolving receptacle.

Some of the features claimed by the manufacturer are: (1) external screw adjustment to compensate for normal wear of rotary seal in service, without removal of rotary joints, thus preventing leakage and reducing maintenance costs: (2) floating rotary seal, made of special graphite composition, is self-aligning in any direction, axially as well as radially, eliminating leakage often caused by misalignment of rotary shaft; (3) pressure equalizing chamber relieves rotary seal of excess pressure, reduces friction, wear, and power consumption. Standard sizes from $\frac{1}{2}$ in. to $1\frac{1}{4}$ in. IPS with larger sizes now in manufacture. Joints are available in syphon and single-flower types.

For more information on this rotary joint, write to the manufacturer.

Seamlex Co., Inc.,
4123—24th St., Long Island City, N. Y.

Oil Hydraulic Cylinders Have Rotatable Heads



The new RH series of 2,000 psi oil hydraulic cylinders are of heavy construction, and are compact, giving maximum cylinder size for minimum mounting area. The heads are retained by screw threads giving a stress distribution throughout the attaching areas of the barrel and heads, while at the same time eliminating bolts and tie rods. The heads are rotatable with respect to each other, simplifying location of ports for plumbing.

All sizes and mounting types of cylinders are available with oversize piston rods, and all sizes, except the $1\frac{1}{8}$ in. bore, are available with 2:1 ratio rods. All sizes may be had with either adjustable or non-adjustable cushions, except the $1\frac{1}{8}$ in. bore which has only the non-adjustable type.

Types of mounting available are: foot; rear flange; clevis; front flange; trunnion; and rabbeted. The type shown in the illustration is the front flange model. While these cylinders are designed primarily for oil service, they can be furnished with chrome plated barrels, piston and piston rods, cadmium plated heads, bronze rings, where treated water having at least one part per thousand of soluble oil, is the working medium.

Pathon Mfg. Co.,
1731 Central Ave., Cincinnati 14, Ohio

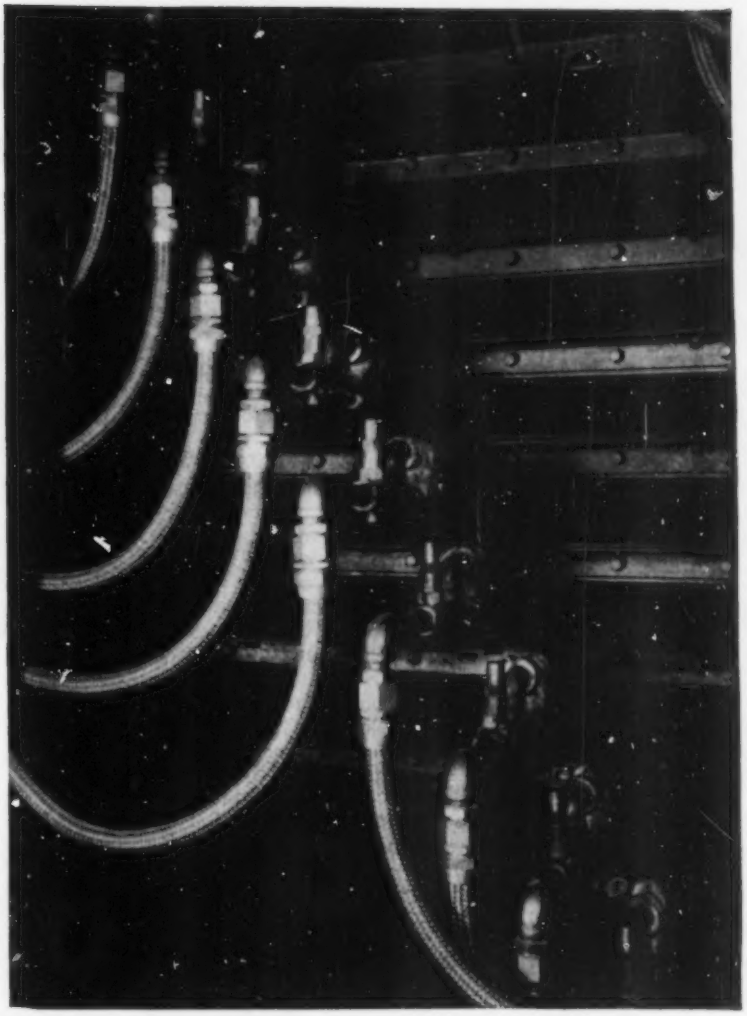
GASKETS AND PACKINGS for improved service under many different conditions are now being made out of: teflon, Kel-F, neoprene, silicon rubber, the phenolics, and other plastics. Complete design and fabrication for: gaskets, packings, washers, spacers, seals, shims, and bushings.—Auburn Mfg. Co., 300 Stack St., Middletown, Conn.

FED BY A 10 KC SQUARE WAVE at 5 v min., the new model 133 harmonic generator supplies harmonic voltages of this input at every 10 kc point up to 15 mc. Containing its own power supply, it operates from standard 115 v, 50/60 cps, power, using 25 watts. Designed for use in an instantaneous frequency comparison arrangement.—Sierra Electronic Corp., 830 Brittan Ave., San Carlos, Calif.

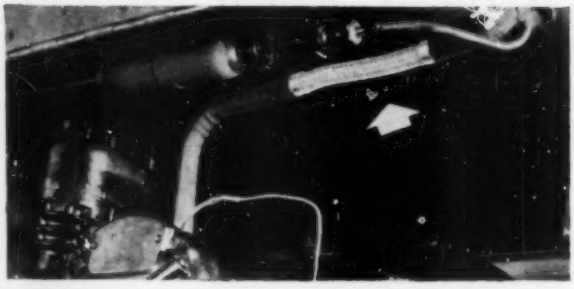
CONTINUED ON PAGE 222

News about flexible metal connectors

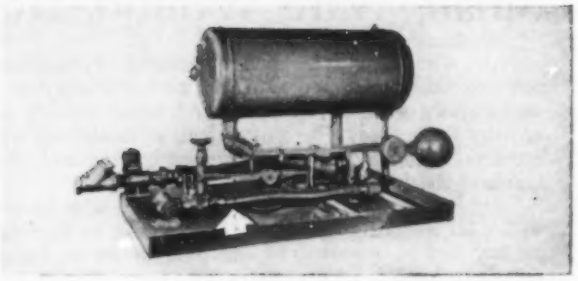
Here they prove dependable for PRESSURE, COLD and HEAT



PRESSURE Harbor Plywood's veneer press uses American ½" I.D. Seamless Bronze Connectors with braid for added pressure resistance. American Flexible Metal Connectors are ideal for this use because they're corrosion-resistant. They come with fittings attached and are easily installed. Manufacturers, like Harbor Plywood, find American Connectors the right solution to tough design problems because of their flexibility, both in assembly and operation, and their long life with little maintenance attention.



COLD For conveying Freon in truck refrigeration systems, The Schnabel Co. uses American Vibration Eliminators. These connectors operate between 10° and 40° F. at 180-200 p.s.i. American Flexible Metal Connectors are the best answer where moving lines must be connected, flexible shafts protected, or assemblies made in restricted spaces.



HEAT Morehead Manufacturing Company uses American Seamless Bronze Flexible Connectors on their "back to boiler" steam trap. This connector has the ability to resist high steam temperature and pressure as well. American Flexible Metal Connectors may also be used to carry corrosive liquids, gases, or semisolids.

62202

WRITE FOR BOOKLET SS-50—*shows how the tubing is designed, used, and installed—gives specifications on tubing and fittings. The American Brass Company, American Metal Hose Branch, Waterbury 20, Conn. In Canada: The Canadian Fairbanks-Morse Company, Limited.*

wherever connectors must move... *American* flexible metal hose and tubing

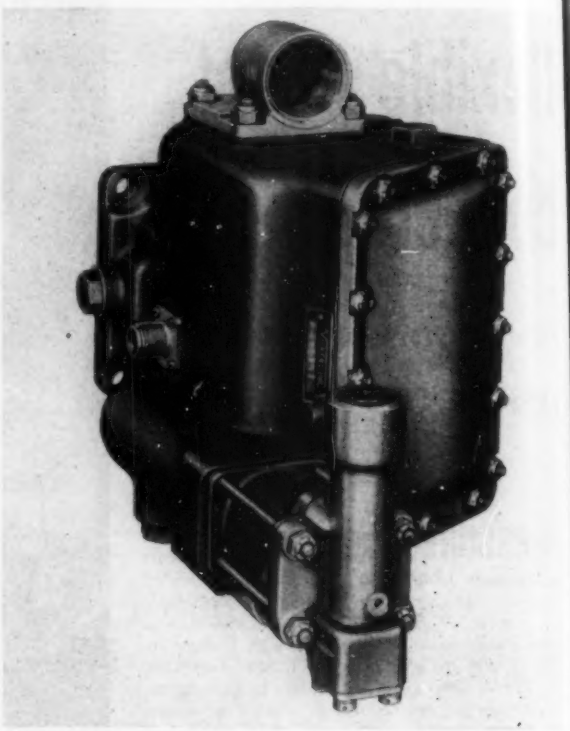
Electrically Depressurized Hydraulic Pump

The new model EDV (electrically depressurized variable) pump is a variable delivery, piston type pump which automatically delivers the hydraulic fluid at rates from zero to full rated volume, governed by the demand of the load. When hydraulic power is not required during intermittent operation, it is possible to depressurize the system by shutting off the pump by means of an electrical signal. When the pump is depressurized, input power to the pump is negligible. This results in engine power and fuel savings, which in one case where eight pumps were used on a jet aircraft, a fuel saving of 700 lb was realized.

The purpose of the electrical depressurizing feature is to relieve loads on the pump when there is no system demand for hydraulic fluid. The unloading feature can be controlled either automatically by direct signals, from the hydraulic system actuating levers, or it can be separately controlled by toggle switches. There is no time lag on a depressurized pump when there is a work demand. It is always turning at normal speed, and no clutch or connection has to be actuated. Rated pressure and flow is available whenever the depressurize signal is removed.

To unload the pump, a solenoid is energized. This actuates valving in the pump so that the pump control system will move the pump yoke to a feathered position. When pressure in the outlet line drops below 100 psi, the line will automatically be shut off. The slight displacement of the pump is then circulated through the case as leakage.

The new design feature of this pump eliminates any need for mechanical clutches or disconnects. This feature is available on all sizes of the variable displacement pump. The sizes of the 3,000 psi pumps range from 0.32 gpm at 1,500 rpm to 23.8 gpm at 1,500 rpm.



Vickers, Inc., 1400 *Oakman Blvd., Detroit* 32, *Mich.*

Small, Wire Wound, Hermetically Sealed Resistors

New wire wound, hermetically sealed, sub-miniature resistors, series 1166 and 1167, are now available for use under severe weather conditions, and where stability and accuracy are needed. The resistors will withstand salt water immersion, humidity, and temperature cycling, and vibration and shock testing.

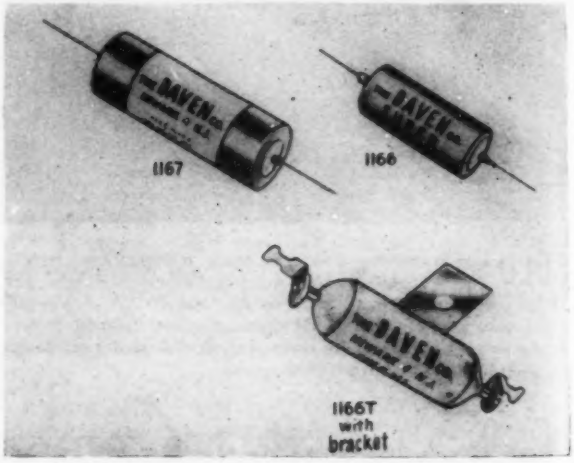
Series 1166 and 1167 are available with wire leads or with solid terminals. Mounting brackets can be furnished, or they can be mounted by clamping or by an integral mounting bracket.

In the construction of these units, a metal cylindrical case with special hermetic button seals at each end, is used.

These units are available with temperature coefficients as low as 20 parts per million per degree centrigrade. Tolerances as close as ±0.1 percent can be supplied; all resistance values are obtainable in this series. The wattage for series 1166 is ½; for 1167 it is 1 watt.

The new hermetically sealed, sub-miniature resistors are the first wire wound resistors available with complete hermetic sealing in such small sizes.

Dimensions, series 1166: length 1 in., dia, 13/32 in.; No. 20 AWG solid tinned leads 2½ in. long. Series 1167: length, 1⅝ in.; dia., 19/32 in.; same leads. Series 1166T: with bracket 1 in. long; 13/32 in. dia.; over-all length, 2 1/16 inches. These units meet all the requirements of specification JAN-R-93 for type RB51A.

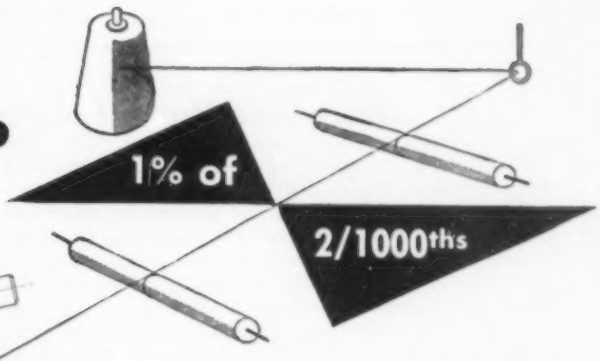


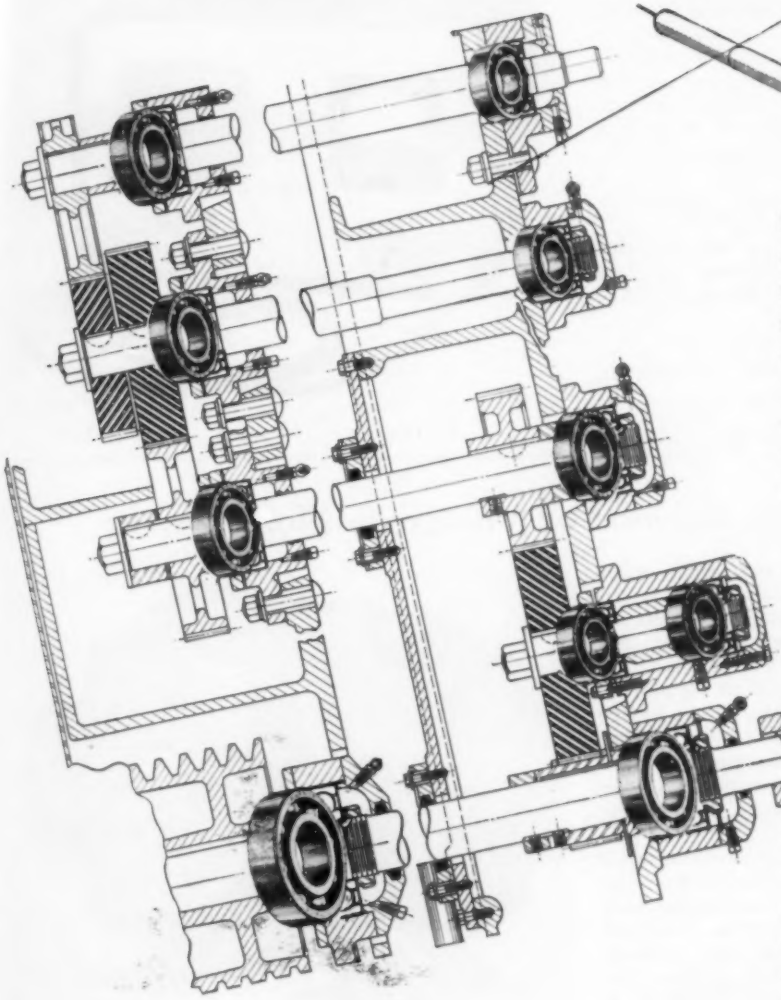
For further information, write to the manufacturer.

Daven Co., 191 *Central Ave., Newark* 4, *N. J.*

CONTINUED ON PAGE 224

SETUP
that holds tolerance to





If you are familiar with machine designing, you'll consider this a "neat" piece of engineering. Such precision is actually achieved on mammoth synthetic thread twisters developed by Whitin Machine Works. The twisters stretch thread to a uniform .002 of an inch diameter and hold that diameter to within a 1% tolerance down a 40 foot line of spindles.

A sectional view of the head end which controls the "feed rolls" and "draw rolls" shows the Fafnir Ball Bearing setup that helps to keep their relative velocity absolutely constant . . . a "must" to produce such an amazing degree of accuracy. The Extra-Precision ball bearings used are made by highly trained operators on special equipment controlled by elaborate inspection devices.

Whatever your bearing problem, a few minutes spent with a Fafnir representative may help you solve it equally as successfully. Fafnir's experience is not limited to just a few industries . . . it's industry-wide. The Fafnir Bearing Company, New Britain, Conn.

Bearings used
Fafnir Extra-Precision Ball Bearings of the 200 (Light) and 300 (Medium) Series are shown in the ten locations above.

FAFNIR
BALL BEARINGS

MOST COMPLETE LINE IN AMERICA

Standard Radial Ball Bearings

Power Transmission Units . . . all types and sizes

Wide Inner Ring Ball Bearings with Mechani-Seals

Electronic Probe Locates Vibrations

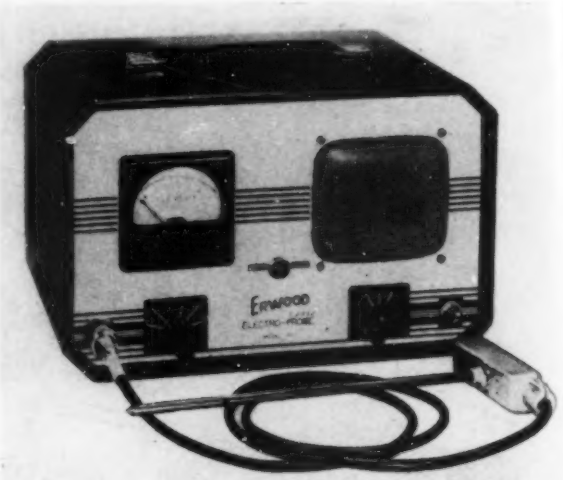
Incorporating a sensitive vibration pickup probe and a 3 stage amplifier, this electronic trouble spotter becomes a third ear that accurately locates and analyzes the noises and vibrations in mechanical devices while they are in operation. The instrument is said to be a thousand times more perceptive than the human ear, but unaffected by airborne noises, because it is sensitive only to vibrations at the point of contact. The speaker and headphones will give an audible comparison of vibration sounds within the range of 60 decibles; the calibrated meter will give a visual indication.

By establishing a systematic check of critical points on running motors and machines, it will make it possible to detect developing trouble before the failure occurs.

The probe can be used also for locating leaks and stoppages in fluid piping systems, locating origins of structural vibrations, analyzing airborne sounds, and the inspection of parts and sub-assemblies.

The probe operates on 36 watt, 110-120 v, a-c, 60 cycle. Dimensions are 10 x 6½ x 5¾ inches. Weight is 14 pounds.

Erwood Inc., 1770 *Berteau St., Chicago* 13, *Ill.*



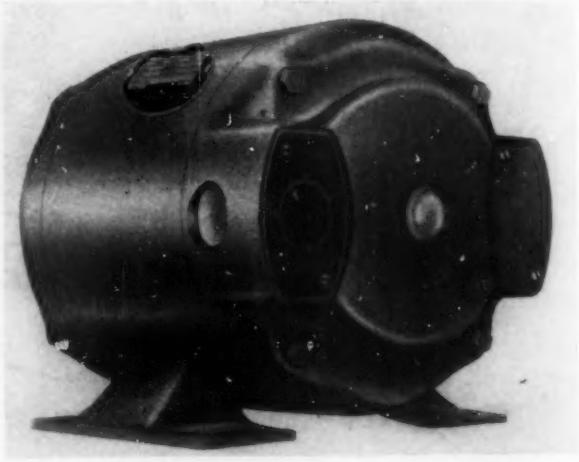
Switch Changes Rotation or Voltage on Motor

Known as the rota-volt selector, this new switch makes it possible to change the rotation or the voltage on a capacitor motor within a few seconds. The rota-volt permits the motor to have four different combinations of rotation and voltage from one standard motor, either 115 or 230 v, and either clockwise or counter-clockwise direction. It also reduces high motor inventories by having the various voltage and rotation combinations, and makes possible the stocking of fewer units. In addition, on a motor equipped with this new device, there are only 2 leads to connect. All the trouble at the terminal plate is eliminated, because the leads are permanent.

The selector is now regular equipment on the capacitor start-induction run ⅙, ¼, ⅓, ½, and ¾ hp motors manufactured by this company. These motors are a-c single phase, 115 or 115/230 v, 50 or 60 cycles, drip-proof protected, and 40 C rise, continuous duty. They are open or totally enclosed; face or flange mounted, with a capacitor built inside the motor frame where it is safe from damage.

Known as the power-poise motors, they are started by a capacitor; after the centrifugal switch operates, the motor runs on induction. These motors have high starting torque and are used primarily on stokers, small pumps, blowers, fans, air conditioning units, and similar applications requiring long life.

The Brown-Brockmeyer Co., Dayton 1, *Ohio*



Self Extinguishing Laminating Plastic

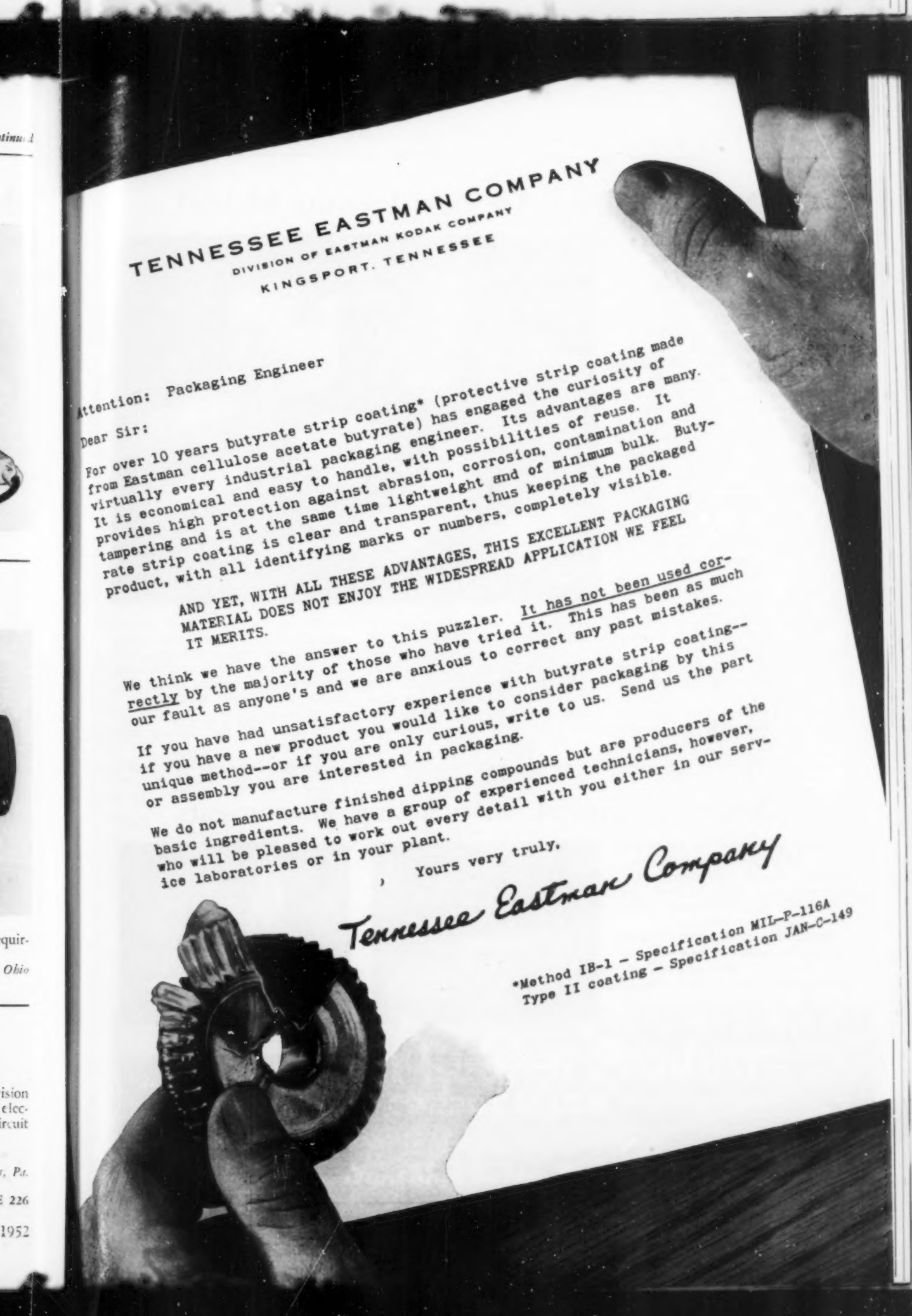
Flame retardant laminated plastics, expected to have wide usefulness in electronic, aircraft and other applications, are now available in all the standard grades and forms usually made by this company. The flame retardant feature has no detrimental effect on machining properties.

In a test, the fire resistant plastic was exposed to the flame of a bunsen burner for 15 seconds, and then removed. Although required by Underwriters Laboratories to extinguish itself in 60 sec., the new plastic had burned out in 19 seconds.

Some applications are: in television receivers printed circuits; and electrical components such as circuit breakers and aircraft equipment.

Synthane Corp., Oaks, Pa.

CONTINUED ON PAGE 226



TENNESSEE EASTMAN COMPANY
DIVISION OF EASTMAN KODAK COMPANY
KINGSPORT, TENNESSEE

Attention: Packaging Engineer

Dear Sir:

For over 10 years butyrate strip coating* (protective strip coating made from Eastman cellulose acetate butyrate) has engaged the curiosity of virtually every industrial packaging engineer. Its advantages are many. It is economical and easy to handle, with possibilities of reuse. It provides high protection against abrasion, corrosion, contamination and tampering and is at the same time lightweight and of minimum bulk. Butyrate strip coating is clear and transparent, thus keeping the packaged product, with all identifying marks or numbers, completely visible.

AND YET, WITH ALL THESE ADVANTAGES, THIS EXCELLENT PACKAGING MATERIAL DOES NOT ENJOY THE WIDESPREAD APPLICATION WE FEEL IT MERITS.

We think we have the answer to this puzzler. It has not been used correctly by the majority of those who have tried it. This has been as much our fault as anyone's and we are anxious to correct any past mistakes.

If you have had unsatisfactory experience with butyrate strip coating--if you have a new product you would like to consider packaging by this unique method--or if you are only curious, write to us. Send us the part or assembly you are interested in packaging.

We do not manufacture finished dipping compounds but are producers of the basic ingredients. We have a group of experienced technicians, however, who will be pleased to work out every detail with you either in our service laboratories or in your plant.

Yours very truly,

Tennessee Eastman Company

*Method IB-1 – Specification MIL-P-116A
Type II coating – Specification JAN-C-149

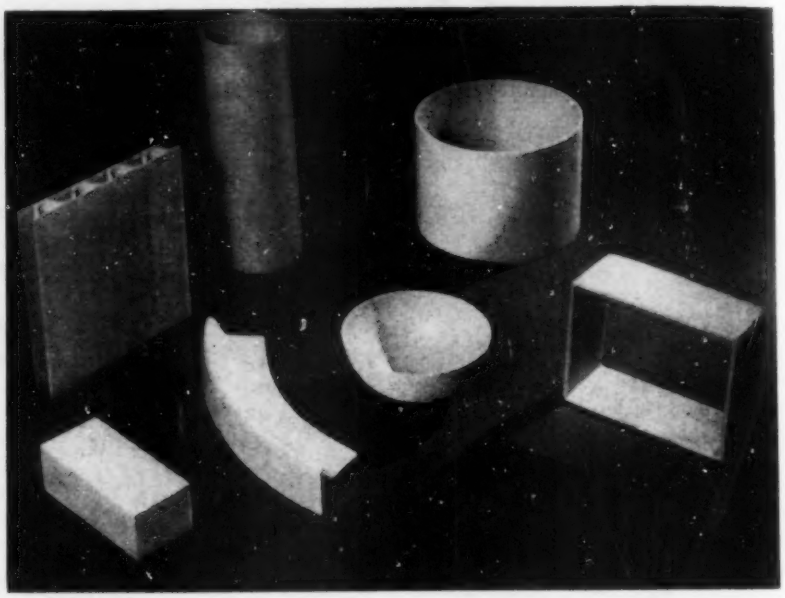
New Laminates Are Low Pressure Molded

Low pressure laminates with a high degree of heat stability are now molded of glass cloth, and a silicone bonding resin at pressures from 3 to 30 psi. They will withstand continuous exposure to temperatures in the range of 500 F, and intermittent exposure to as high as 900 F.

Physical and electrical properties of these materials are similar to those of conventional high pressure silicone-glass laminates molded at 1,000 psi or higher. Their mechanical strength is said to be superior to silicone-bonded moldings of chopped glass, mica, asbestos, or other inorganic fillers.

Finished laminates weigh less than aluminum or magnesium and are said to be stronger than either at 500 F. Smooth, non-porous, and easily machined, they are water repellant and resistant to most commonly used chemicals. Laminating stocks may be preformed and used to prepare complex shapes either by bag molding, or in light metal molds. Flat sections can be laminated in thicknesses ranging from 0.01 to 2.00 inches.

The 2104 silicone resin has a low viscosity at the laminating temperature of 345 F, and a gel time that can be controlled by adding a catalyst.



Press time for low pressure silicone-glass laminates is 15 min. for an $\frac{1}{8}$ in. section. However, maximum heat stability requires an afterbake of from 100 to 170 hrs at 500 F. In many applications high temperatures may affect this afterbake during use, eliminating most of the over-curing time.

In a test made with a themocouple attached to the silicone resin bonded laminate, after 15 min at a temperature of 800 F the laminate was untouched. The same test on an organic resin bonded laminate resulted in the piece burning away almost completely.

Dow Corning Corp., Midland, Mich.

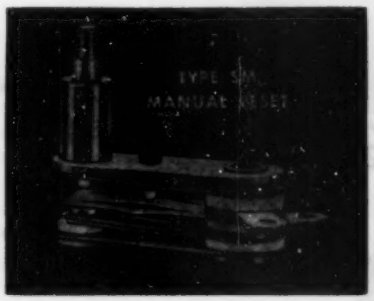
Sensitive, Bimetal, Snap-Acting Thermostats

Typical applications for a new line of bimetal strip thermostats are: vaporizers, controls for furnace fans, sterilizers, steam irons, flat irons, and other devices requiring sensitive, snap-action control characteristics.

The new line of snap-acting thermostats are designated as type SA, and are available in either adjustable or non-adjustable styles. The manual-reset style is designated as type SM.

Available for either single-pole single-throw or for single-pole double-throw action, these thermostats can operate on differentials as narrow as 10 F, or as wide as 100 F.

Completely interchangeable with the type S thermostats made by this company, or units of similar dimensions, the new type SA thermostat line features an electrically independent bimetal element that reduces artificial cycling and life-shortening "jitters." Contact pressure is positive until the instant the silver contacts snap open.

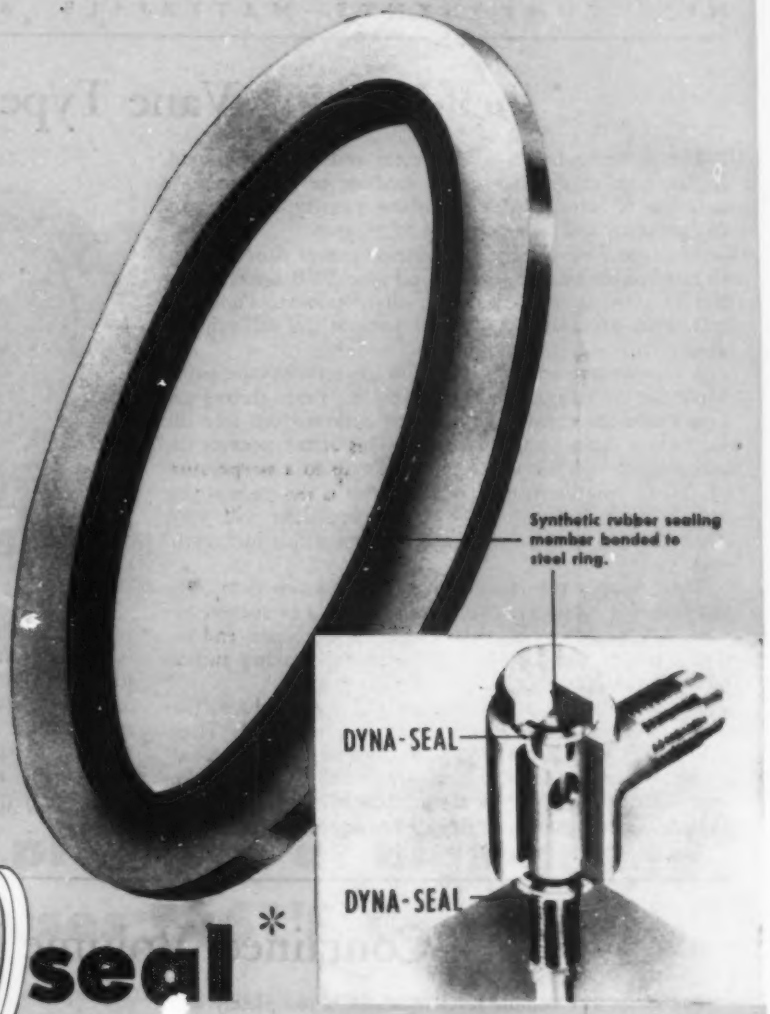


In general, type SA and SM thermostats are rated at 15 amp at 120-240 a-c, and at 30 d-c.

Stevens Manufacturing Company, Inc. 69 S. Walnut St., Mansfield, Ohio

CONTINUED ON PAGE 228

PRP announces a New Product



...the Dyna-Seal*

thoroughly proved — a simple face-to-face seal!

*trademark registered U.S. Patent 2,455,982

Synthetic rubber sealing member bonded to steel ring for sealing circular flat surfaces, bolt heads, rivet heads, flanges, special fittings — no grooves necessary. Seals all pressures against water, all types of petroleum products, many other fluids and gases. Countless applications. Write for free handbook.

Precision Rubber Products CORPORATION

The "O" Ring Specialists

Dept. 3, Oakridge Drive, Dayton 7, Ohio

Self-Priming Vane Type Pumps

For pumping hot and cold, clear and vaporous liquid, in moderate capacities, against medium or high heads, a new line of standard design turbine vane type pumps are self-priming, and will pump up to 58 gpm.

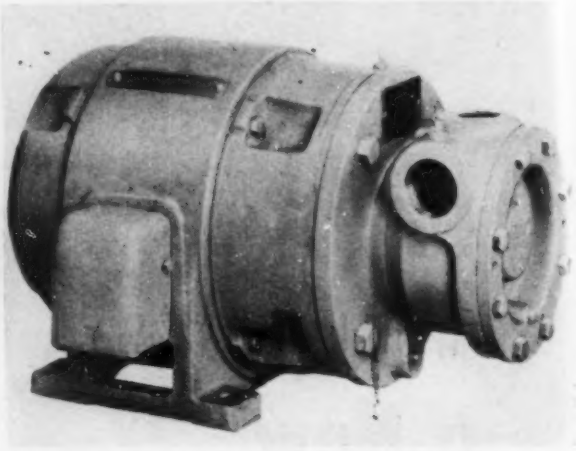
The type TVE refers to the line of pumps close coupled to face mount electric motors, and type TVB refers to the line of flexible coupled electric drive pumps. Pumps in both lines are available with or without the self-priming device.

A regenerative action is caused in the turbine vane pump when the centrifugal force given by the vanes throws the liquid into the channel and is then deflected out into the succeeding vanes of the impeller. This action permits the pumping of light or vaporous liquids up to a temperature of 250 F. Another feature of the pump is the maintaining of a constant capacity where head conditions will vary. These liquids must be clear and without solids in suspension.

There is only one moving pump part in this pump, the free running impeller. Because side and top suction are used in the case design, disassembly of the liquid end for repair is easy and may be done without breaking suction or discharge piping.

The self-priming device consists of a trap on the suction and an air separating chamber on the discharge. These attachments will keep liquid in the pump case at all times, which is necessary for self-priming. The suction trap includes a strainer for further protection to the pump.

Standard construction materials for handling clear water



is with cast iron case, bronze impeller and liners, stainless steel shaft and a standard mechanical shaft seal. Cover liner, impeller and inner liner are all replaceable.

Capacity range of 3,500 rpm is up to 58 gpm; at 1,750 rpm, up to 56 gpm. Head range at 3,500 rpm is up to 800 ft; at 1,750 rpm, up to 300 feet. Motor sizes up to 20 hp are available at 3,450 rpm and up to 7½ hp at 1,750 rpm.

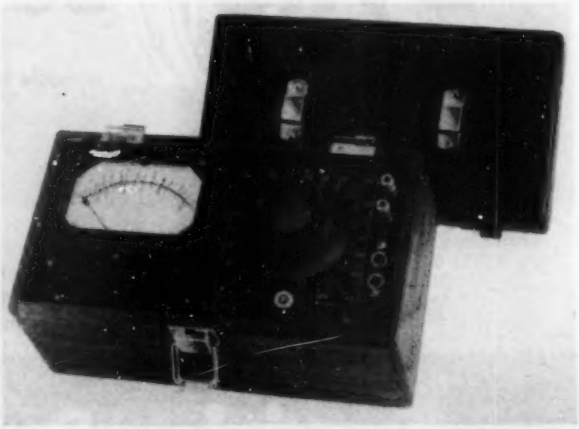
Food Machinery and Chemical Corp., Peerless Pump Div., 301 W. Ave. 26, Los Angeles 31, Calif.

Self-Contained Volume Level Indicator

The series 911 volume level indicator, a completely self-contained unit, has its components especially mounted to withstand rough usage. It requires no batteries or external power supply, and is sensitive to low power levels.

The indicating meter is a copper-oxide type instrument having good characteristics for monitoring purposes. The adjustment is such that the pointer will indicate 99 percent normal deflection at zero vu in approximately 0.3 seconds. Overswing is not more than 1 to 1½ percent. The meter scale is calibrated in vu and percent.

Two meter controls are provided; one a small decade with screw driver adjustment for zero level setting of the meter pointer; the other a constant impedance T type network for extending the range of the instrument in steps of 2 Db. These controls make it possible for all vu meters in one installation to be adjusted to the same scale reading.

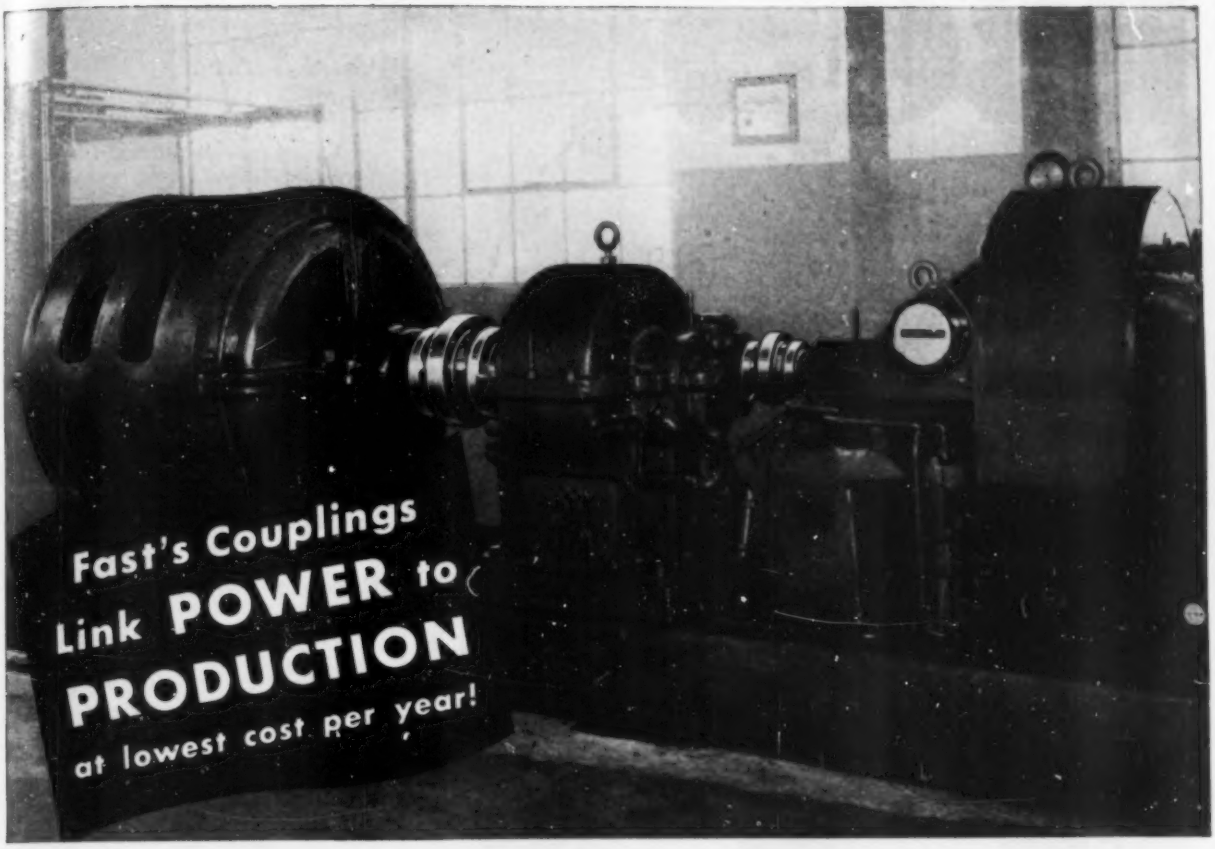


The Daven Co., 191 Central Ave., Newark 4, N. J.

AVAILABLE WITH WIRE LEADS, solder lugs, or screw terminals, a new, easily adaptable toggle switch can be made up as a single-pole, single-throw toggle switch, or a single-pole, single-throw momentary switch, and is rated at 6 amp at 125 v, or 3 amp at 250 v. Measures 1¼ in. in length by ½ in. in width and depth. Available with mounting sleeves from ¼ to 15/16 inch.—Slater Electric & Mfg. Co., Inc., 56 St. & 37 Ave., Woodside, N. Y.

A DRAFTING TEMPLATE has 26 triangles from 3/32 in. to 1 in. with increments in 32nds to ¾ in.; and in ¼ in. from 13/16 to 1 in. Diamonds in size from ¼ to 1 inch.—Rapidesign, Inc., P. O. Box 592, Glendale, Calif.

CONTINUED ON PAGE 230



Every major producer of high-speed equipment uses FAST'S Couplings!

HIGH-SPEED equipment demands components with superior strength, accurate manufacture, long-lasting dependability. That's why it's important to *you* that Fast's Couplings are selected by every major high-speed equipment producer!

Fast's usually outlast the equipment they connect. Many have been in continuous operation for over 30 years, without trouble of any kind. And Fast's longer life saves you coupling dollars, too, because you amortize their cost over many years of trouble-free operation.

For full details on Fast's Couplings and Koppers Engineering Service, write today for your free copy of our catalog. Send to: KOPPERS COMPANY, INC., *Fast's Coupling Dept.*, 238 Scott St., Baltimore 3, Maryland.

Here's How FAST'S Save You Money

Free Service—Koppers free engineering service assures you the right coupling for the job.

Rugged Construction—Fast's still maintains its original design, without basic change or sacrifice in size or materials. Result: freedom from expensive coupling failures.

Lowest Cost per Year—Fast's Couplings usually outlast equipment they connect. Their cost may be spread over many years!

KOPPERS

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THE ORIGINAL GEAR-TYPE

Couplings

INDUSTRY'S STANDARD FOR 32 YEARS

KOPPERS COMPANY, INC., *Fast's Coupling Dept.*
238 Scott St., Baltimore 3, Md.

Gentlemen: Send me Fast's Catalog which gives detailed descriptions, engineering drawings, capacity tables and photographs.

Name _____

Company _____

Address _____

City _____ *Zone* _____ *State* _____

RBC's

PITCHLIGN
TRADE MARK
ROLLER BEARINGS

PITCH CIRCLE ALIGNMENT
for PEAK EFFICIENCY

Wasted energy!
. . . worse
Efficiency plus!
. . . not above
. . . not below
At the pitch line!

Aligned at the *pitch circle*, the most efficient plane for roller guidance, PITCHLIGN rollers are not subject to the internal stresses incurred in other bearings where the cage acts at a point above or below, the pitch circle. In PITCHLIGN bearings, tangential forces are virtually eliminated, since the cage acts *only* in the direction of rotation and at a point coincident with the roller orbit.

PITCHLIGN'S performance potential far exceeds that of precision needle-type bearings. Rollers cannot cock or skew! PITCHLIGN is interchangeable with precision needle bearings, of course. Get the facts! *Write for Bulletin SF-166*

RBC

ROLLER BEARING COMPANY OF AMERICA • TRENTON, N. J.

Giant Vacuum Printing Frame

A giant vacuum printing frame for producing photographic metal templates, is used in conjunction with a simple photographic process, and is said to eliminate the laying out of the design on the template by hand. Equipped with a bank of instant start, slim line fluorescent tubes, it has an overall printing area of 68 by 144 inches. Features: even illumination with no hot spots; automatic timer for exposures from one second to several minutes; quick acting vacuum.

Miller-Trojan Co., Inc.,
1083 W. Main St., Troy, Ohio

Bourdon Tube Type Pressure Switch

A new bourdon tube type pressure switch for use with air, aircraft fuels, hydraulic fluids or lubricating oils, is available to handle pressure in ranges of from 0 to 1,500 psi. Ambient operating limits include a temperature range of from minus 65 to plus

160 F, and operation at all altitudes from sea level to 50,000 feet. The maximum current capacity is 1.0 amp at 50,000 ft. altitudes at 28 volts d-c

The new unit is suited for use in electrical control or warning systems on aircraft where fluid pressure is one of the control parameters.

Hydro-Aire, Inc. 3000 Winona Ave., Burbank, Calif.

Silicon Rubber Bushings On Capacitors

Silicon rubber bushings are now used as standard terminal construction on all hermetically-sealed bathtub type and can type capacitors with rivet lug terminals made by this company.

According to the manufacturers, sili-

simple, easy to use!

speed detailing and specifying!

...yours FREE!

the newest, latest

ALEMITE LUBRICATION FITTING DATA SHEETS

THEY'RE HERE! Available to designers and draftsmen for the first time! A handy, *complete* grouping of the most *complete* line of fittings on the market. Genuine Alemite Lubrication Fittings . . . highest quality fittings from the leader and pioneer in the field of lubrication!

They're here! *Fully detailed. Easy-to-use.* With every fitting illustrated actual size—complete with individual dimensions—ready for transfer to your own blueprints. *No complicated cross reference charts or procedures are involved.*

Don't delay! Important changes in fitting models and dimensions have been made. (Last year's data sheets are no longer complete.) Act now. Send for your FREE copy of these newest, latest Alemite Fitting Data Sheets right away. Clip and mail coupon *today!*

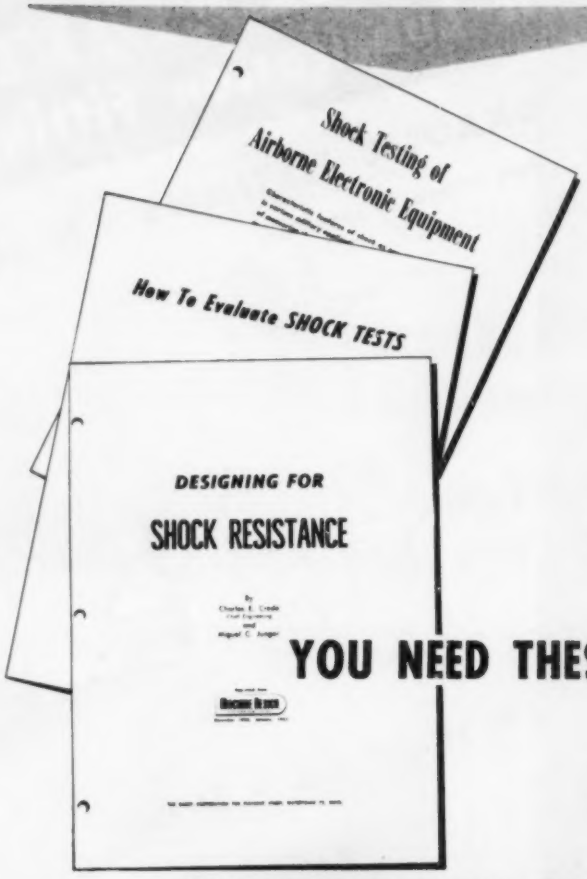
Alemite, Dept. T-83
1850 Diversey Parkway, Chicago 14, Illinois
Please rush me FREE your brand new, up-to-the-minute Alemite Lubrication Fitting Data Sheets.

Name _____
(please print plainly)
Address _____
City _____ Zone _____ State _____

ALEMITE

A PRODUCT OF SW STEWART WARNER

IF SHOCK IS YOUR PROBLEM



YOU NEED THESE 3

ENGINEERING REPORTS

"Designing for Shock Resistance" sets forth the principles used by the Navy Department in design of shock-proof equipment for shipboard applications. *Published in "Machine Design" Dec. 1950 — Jan. 1951.*

"Shock Testing of Airborne Electronic Equipment" describes the characteristics of shock and tells how shock testing machines are used. *A paper presented at the Dayton Airborne Electronics Conference, 1951; later reprinted in "Tele-Tech".*

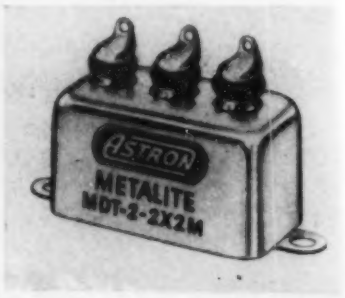
"How to Evaluate Shock Tests" tells how mechanical structures respond to shock and shows how such response can be evaluated under controlled test conditions. *Originally published in "Machine Design" December 1951.*

These Barry reports are part of the complete service we offer in handling shock and vibration problems. When you have an isolation problem, call the nearest Barry representative, or ask our field engineering service to help you.

BARRY CORP.

730 PLEASANT ST., WATERTOWN 72, MASSACHUSETTS

SALES REPRESENTATIVES IN



con rubber bushings give a more positive hermetic seal, and has the approval of the Armed Forces as the preferred terminal construction.

Astron Corp., 900 Passaic Ave., E. Newark, N. J.

Distortion Free Perspective Graphs

A new type of perspective graph has been developed to permit scaling directly from an engineering drawing into an accurate perspective view. These new graphs are said to be free from distortion, and becomes as simple and as fast as an isometric projection.

The graphs are designed to represent an inversion of the six faces of a cube. Each of the six planes is a grid, graduated in true perspective foreshortening, from which dimensions may be plotted and projected.

The set includes seven basic graphs, each graph designed to view the perspective grids at a different angle. (30 x 30 deg, 15 x 45 deg, 45 x 15 deg, 5 x 55 deg, 55 x 5 deg, 7½ x 27½ degrees). Each graph may be used as a top view or, by inverting it, as a bottom view, allowing a choice of fourteen different views. Each of the graphs is practical for distortion-free perspective drawings of any size from 8 x 10 in. up to its full dimension of 30 x 60 inches.

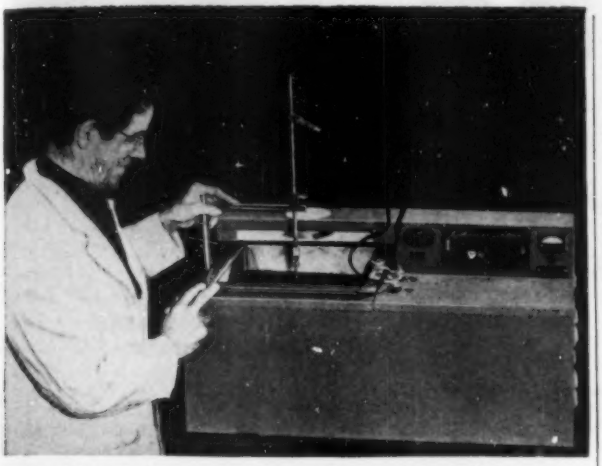
Tech-Art Graphs, 315 S. 15 St., Philadelphia 2, Pa.

Heavy Duty PA Driver Unit

To a line of loudspeaker units has been added the new model SA-30, 30 watt, high efficiency, heavy duty driver unit with a self-contained line matching transformer. Both the driver mechanism and the transformer with its terminal strip are entirely enclosed in a heavy die cast aluminum body. A gland nut cable entrance gives waterproofing of all connections as well as the driver mechanism.

Impedances ranges from 45 to 2,000 ohms. Other features include the rim-

CHROME PLATE YOUR TOOLS IN YOUR OWN SHOP . . . FAST



Model A-50 Chromaster is a bench-mounted unit for plating up to 25 sq in. Built-in power supply operates from single phase 110/120 v 60 cy. a-c.

Revolutionary New Self-Contained Plating Unit Already Adopted by Many Leading Firms to Lengthen Tool Life, Reduce Shutdowns

Chromaster has come along at the right time.

With delivery of new tools getting tighter, demands on your own machinery more pressing, you'll welcome Chromaster as a means of increasing tool life, salvaging worn tools and parts, reducing tool inventories, lessening machine downtime.

Chromaster permits you to conduct your own plating operations, in small space, anywhere in your plant, without skilled help or prior plating experience.

No More Mystery In Chrome Plating

In the past, many firms have preferred to have industrial chrome plating done outside. Techniques were too specialized, equipment too complicated and costly. Consequently, they had the inconvenience of shipping tools, waiting for delivery.

Now, with Chromaster, these objections have been removed. Technique is simple. Equipment is inexpensive. Tools can be plated quickly. Plated tools last longer, permitting reduction in inventories and reducing frequency of machine shutdowns.

Anyone Can Operate Chromaster

Chromaster simplifies industrial chrome plating. Thanks to a secret formula, Chromasol solution permits plating at room temperature. Average plating time is less than with conventional processes. No heating needed. Thorough cleaning is only preparatory work. Plate is hard, even, accurately deposited. No after finishing or grinding is usually needed.

Applications include drills, taps, dies, jigs, reamers, gears, cams and other component parts made of steel, iron and most non-ferrous metals.

Hundreds of manufacturers, among them makers of aircraft, automobiles, dictating machines, electric appliances, glassware, motors, tools, are now using Chromaster. (Names on request)

Chromaster is made by Ward Leonard Electric Co., leading manufacturer of industrial controls. Address Industrial Chrome Division, 63 South Street, Mt. Vernon, N.Y., for full particulars.

Chromaster Plating Multiplies Tool Life Up To Ten Times

Now Chromaster enables you to do chrome plating in your own shop, obtaining a low friction hard plate of high density and adhesion.

Gives tools a hard, low-friction surface that survives 2 to 10 times normal tool life.

Secret Formula Does The Trick

Unlike other plating solutions, it requires no heating, no elaborate heating system.

Chromasol solution used with Chromaster is ready for dilution with water, no "doctoring" required.

Famous Aircraft Manufacturer Gets 325% Increase In Drill Efficiency

Comparative studies of high speed drill performance convinced a famous aircraft manufacturer to install Chromaster.

Drilling through S320-CL "N" steel, 180,000 – 195,000 tensile strength, holes 3/4 in. deep, drill size 5/16 in., Chromasol plated drills averaged 34 holes per drill as against 8 per non-plated drills.

A Little Chromasol Goes A Long Way

Economical to begin with, Chromasol solution gives amazingly long service.

One charge lasts more than 500 hours plating time – enough for many thousands of ¼-20 taps.

FEATURES

- **3½ minutes to chrome plate**
- **Lengthens tool life up to 10 times**
- **Reduces tool inventory**
- **No previous plating experience needed**

SEND COUPON FOR FREE BULLETIN

WARD LEONARD ELECTRIC CO.
Industrial Chrome Division
63 South Street
Mt. Vernon, N.Y.

Please send your free bulletin on Chromaster. My type of business is

.....

Name..... **Title**.....

Company .....

Address .....

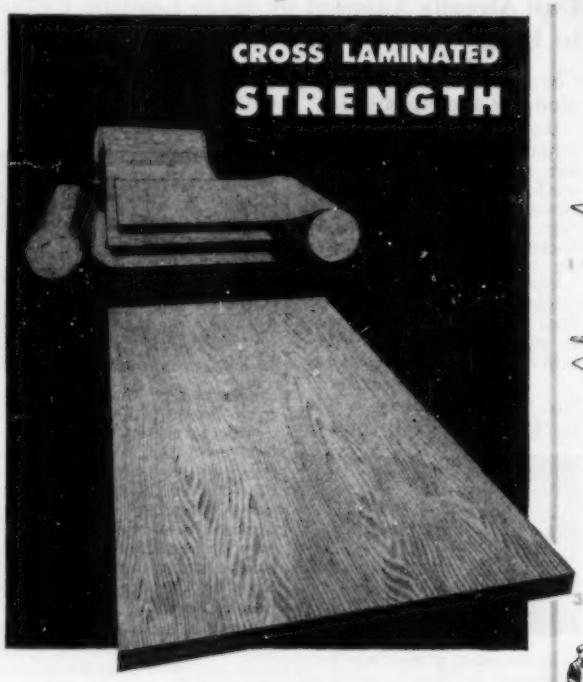
City..... **Zone**..... **State**.....

Chromaster

INDUSTRIAL CHROME DIVISION
WARD LEONARD ELECTRIC CO.

FOR YOUR INDUSTRIAL HARD CHROME REQUIREMENTS

Only plywood gives you all 6

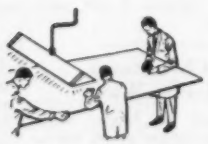


1 Cross Laminated Strength

2 Workability

3 Attractive Appearance

4 Large Panel Size

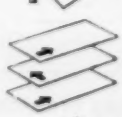

5 Tested Quality

6 Light Weight

POUND FOR POUND, Douglas fir plywood is one of the strongest of all building materials. It's *real wood*, cross-laminated to distribute wood's great along-the-grain strength in *both* directions. It's tough, durable, split-proof, puncture-proof. Won't crack, chip, break or shatter. Shrugs off blows that would tear, dent or split other heavier, bulkier materials.

If you have a building, remodeling or manufacturing job where light-weight strength, workability and work-speeding size pay off, plan it with plywood. For detailed information about plywood uses and properties, write Douglas Fir Plywood Association, Dept. 458, Tacoma 2, Washington.

Douglas fir plywood is real wood, made by "unwinding" giant logs



into thin wood sheets which are inseparably cross-laminated

to form large, light panels having beauty and great strength

Douglas Fir
Plywood
AMERICA'S BUSIEST BUILDING AND INDUSTRIAL MATERIAL

centered, alnico V magnet assembly, resulting in a vibration and shock proof unit; a diaphragm voice coil assembly that automatically centers in the magnet gap, permitting quick replacement.

University Loudspeakers Inc.,
80 S. Kensico Ave., White Plains, N. Y.

New Rubber-Filled Phenolic

A new flexible type phenolic molding compound has a low modulus of elasticity which permits its use for molding in thin sections around inserts. Having a synthetic rubber filler, it absorbs shock more readily than standard wood-flour, or flock-filled materials. Called 14780 Black, it is said to mold equally well by closed-mold compression molding and may be preformed in any automatic preforming equipment. Flexural strength is 9,000 psi, and tensile 6,000 psi, minimum. Not recommended for applications where continuous heat of more than 250 F is required.

Durez Plastics & Chemicals, Inc.,
N. Tonawanda, N. Y.

Fast Hook-Up Heater Switch

A new series of heater switches with a simple method for wiring, eliminates the need for binding screws, clips or other special fittings.

The hook-up is accomplished by pushing the stripped end of standard-wire, either solid or stranded, into one of the switch's autolock connections. A spring clamp automatically locks the wire in place with a positive connection. For re-wiring, the wire is released by depressing a small lever.

The new wiring system used in these diamond H series 850 switches is said to save man hours of assembly time, as well as material costs, for manufacturers of ranges and similar appliances using heater switches. The

AIR PRESSURE GAGE
LIQUID LEVEL INDICATOR
LIQUID CHAMBER OUTER SHELL 6" O.D. x .050" SEAMLESS COPPER TUBE
COMPRESSED AIR CHAMBER
SEAMLESS COPPER TUBE PUMP CASING
SEAMLESS BRASS TUBE HAND PUMP (FOR RECHARGING; AIR-LINE CONNECTION IS IN BONNET)
CAST RED BRASS BASE AND BONNET (TUBE GROOVES ARE MACHINED)

Phister Fire Extinguishers, featuring "all copper and brass construction," are made in a variety of portable sizes and are readily recharged after use. Copper and copper-alloy components provide high resistance to corrosion. Other Anaconda Alloys are used for valve parts, packing nuts, couplings, bushings, gage guards, hose clips, pump parts, etc.

"BUILT-IN" FIRE-FIGHTING POWER *that lasts*

In the home or plant, the cry of "fire" is always frightening, and infinitely more so if the extinguisher fails to work.

Based on several such experiences, and goaded by the conviction that "any fire costs more than a dependable fire extinguisher," founders of The Phister Manufacturing Company of Cincinnati, way back in 1918, decided to design an extinguisher "superior to any on the market" and combining these four *musts:*

1. It must maintain constant air pressure—without pumping.
2. It must be ready to go into operation instantly . . . even after years of disuse.
3. Air pressure and liquid level gages must indicate condition at a glance.
4. Most important, dependable, corrosion-resistant metals must be used to eliminate the most common cause of failures.

Since the first Phister Extinguisher was built to these specifications, there has not been a single record of failure by corrosion.

Over the years, The American Brass Company has supplied Phister with Anaconda Copper and Copper Alloys in many commercial forms, filling precise requirements of corrosion resistance, close-tolerance dimensions and low-cost fabricating qualities. Perhaps our Technical Department could work with you in a similar way? Write The American Brass Company, General Offices, Waterbury 20, Connecticut.

You can depend on

ANACONDA

COPPER & COPPER ALLOYS

AMERICAN CHEMICAL PAINT COMPANY
AMBLER CHEMICALS ACP PROCESSES PENNA.

Technical Service Data Sheet
Subject: PROTECTING ALUMINUM WITH ALODINE®

"ALODINE" No. 100

"Alodine" No. 100 forms an amorphous phosphate surface on aluminum which is thin, tough, durable, non-metallic, continuous with and a part of the basis metal. The "Alodine" film anchors paint, prolongs paint life, and protects aluminum exposed unpainted to the atmosphere.

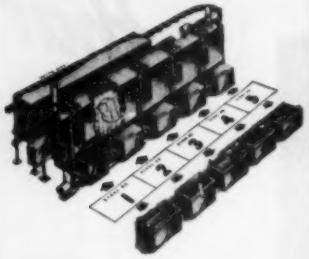
With the "Alodine" No. 100 bath at its normal temperature of 120° F., coating time by immersion approximates 1½ minutes—and by spraying, 15 to 20 seconds. Coating times and bath temperatures can be varied to suit operating conditions.

"ALODINE" No. 600

"Alodine" No. 600 forms corrosion-resistant coatings that provide excellent protection for unpainted aluminum and also make an effective paint-base. This grade is recommended for use in place of "Alodine" No. 100 on aluminum parts that are to remain unpainted or to be only partly painted; and on *all* aluminum castings and forgings whether or not these are given a paint finish.

"ALODINE" FLOW SHEETS

MULTI-STAGE POWER WASHER FOR SPRAY ALODIZING



IMMERSION TANKS FOR DIP ALODIZING

PROCESS SEQUENCE

1. Clean 2. Rinse 3. "Alodine" 4. Rinse 5. Final Rinse

NOTE: Equipment can be of mild steel throughout, except the "Alodine" stage which must be of acid-resistant material.

"Alodine" No. 600 is applied at room temperature (70° to 120° F.). Recommended coating times are 3 to 5 minutes for an immersion process and 1 to 1½ minutes for a spray process.

COATING DATA	"ALODINE" NO. 100	"ALODINE" NO. 600
COMPOSITION	Amorphous phosphate.	Amorphous mixture of metal oxides and chromates.
COLOR	Depending on alloy treated, color range is from an iridescent blue-green to a dark slate gray.	Depending on time of treatment, color range is from golden iridescent to light brown.
THICKNESS	From 0.01 to 0.08 mil. No appreciable dimensional changes occur when aluminum is Alodized.	From 0.005 to 0.01 mil. No appreciable dimensional changes occur when aluminum is Alodized.
WEIGHT	50 to 300 mgs. per square foot. Optimum: 100 to 200 mgs. per square foot.	35 to 50 mgs. per square foot.
SOLUBILITY	Insoluble in water, alcohol, solvents, etc. Insoluble in most dilute acids and alkalis. However, strong acids and alkalis which attack aluminum may penetrate the "Alodine" film and react with the underlying metal. Slightly soluble in concentrated nitric acid. Soluble in molten sodium nitrate, etc.	Insoluble in alcohol, water, solvents, etc. Soluble in strong alkalis and acids.
ELECTRICAL PROPERTIES	High dielectrical resistance.	This coating is electrically conductive. Aluminum coated with "Alodine" No. 600 can be shielded-arc welded or spot welded.
HEAT STABILITY	Unimpaired at temperatures that melt aluminum.	Unimpaired at temperatures that melt aluminum
FLEXIBILITY	Integral with and as flexible as the aluminum itself. Can withstand moderate drawn.	Integral with and as flexible as the aluminum itself. Can withstand moderate drawn.
ABRASION RESISTANCE	Approximately 90% of that provided by chromic acid anodized aluminum.	Approximately 90% of that provided by chromic acid anodized aluminum.
CORROSION RESISTANCE	Painted—superior to chromic acid anodizing. Unpainted—comparable with chromic acid anodizing. Meets MIL-C-5541 and other Government Finish Specifications.	Exceeds requirements of MIL-C-5541 and even AN-QQ-A-696a (anodic films)
PAINT-BONDING	Excellent. Equal to or superior to anodizing. Meets MIL-C-5541 and other Government Finish Specifications.	Excellent. Meets MIL-C-5541 and other Government Finish Specifications.
TOXICITY	Non-toxic.	Non-toxic.
BIMETALLIC CORROSION RESISTANCE	Shows good resistance against bimetallic or galvanic corrosion.	Shows good resistance against bimetallic or galvanic corrosion.

CHEMICALS ACP PROCESSES **WRITE FOR FURTHER INFORMATION ON "ALODINE" AND ON YOUR OWN ALUMINUM PROTECTION PROBLEMS.** CHEMICALS ACP PROCESSES

switches are small in size, and can be close mounted either in line or cluster arrangements to save space and simplify assembly and operation of the appliance.

They are UL approved, and will be available in standard, heavy and horsepower ratings in a variety of standard and special circuits including off-on, 3-heat, 5-heat, 7-heat, and 9-heat circuits with one-hole, two-hole or special mounting arrangements.

Hart Mfg. Co., 110 *Bartholomew Ave., Hartford, Conn.*

Two Subminiature Double Triodes

Subminiature double triodes, types 6111 and 6112 have been designed for use at relatively high ambient temperatures where long life and stable performance are required under shock and vibration conditions in compact, light weight equipment. The 6111 is a medium-mu double triode in a T-3 envelope with a filament voltage of 6.3 v, filament current of 300 ma, transconductance of 5,000 micromhos, and an amplification factor of 20. The 6112 is a high-mu double triode in a T-3 envelope with the same filament current and voltage, transconductance of 2,500 micromhos, and an amplification factor of 70.

Sylvania Electric Products, Inc., Radio Tube Div., 1740 *Broadway, New York* 19, *N. Y.*

A NEW LINE OF HERMETICALLY SEALED SELENIUM RECTIFIERS are available in metal cases filled with inert gas, and provided with standard tube terminals to fit standard sockets. Rated at 390 v rms input; 550 v peak inverse; 120 milliamp, 160 v d-c out-

42 years of service to industry

DIE CASTINGS by ...

Stewart

We take pride in being known by the customers we keep.

A DIVISION OF... STEWART SW WARNER

STEWART DIE CASTING

CHICAGO, ILL., 4535 FULLERTON AVE... BRIDGEPORT, CONN., 275 WARREN ST.

COLD FACTS

about YORK'S new ICE CUTTER

YORK FLAK-ICE AUTOMATIC ICE MAKER, MODEL DER-2

ICE HARVESTING SYSTEM

ATLANTIC'S ICE CUTTER CASTING

AN IMPORTANT COMPONENT of York Corporation's most recent development, the York-Flakice Automatic Ice Maker, is Atlantic's ice cutter casting. It cuts the ice into curved flakes... so delicate they will not damage or puncture delicate rose petals.

YORK'S ORIGINAL CONCEPTION of the ice cutter... a vital part of the ice harvesting system ...consisted of three stainless steel parts which had not only to be machined, but welded together.

ATLANTIC'S ENGINEERS suggested a design that eliminated these costly operations and increased the productive efficiency of the ice cutter. Six spiral blades on a center shaft were all plaster mold cast in one piece of Atlantalloy #3! High Tensile Manganese Bronze... an alloy of great endurance and strength.

York will testify that Atlantic's all-in-one-piece ice cutter casting surpassed all requirements for high physical values, closely-held tolerances, satin-smooth finish, fine-grained structure, clean-cut surfaces... and afforded them substantial savings over former costs.

Find out how the Atlantalloy plaster mold casting process can help solve some of your problems. Write for a free copy of "High Quality Precision Castings for Industry" today!

ATLANTIC CASTING and ENGINEERING CORP.

Established 1937

721 Bloomfield Avenue • Clifton, N. J. • PRescott 9-2450

put at 35 C ambient.—International Rectifier Corp., 1521 E. Grand Ave., El Segundo, Calif.

A NEW SUB-MINIATURE SLIP RING ASSEMBLY combines minute size with good dimensional accuracy. It has 32 slip rings with individual color coded leads. Overall length of the assembly is 1.011 inches. Ring width, 0.020 in.; barrier width 0.010 in.; ring dia. 0.141 in. Assembly meets insulation requirements of 500 v hi-pot inter-circuit.—Electro Tec Corp., South Hackensack, N. J.

A MAGNETIC PROBE of super-magnetic alloy, is no larger than a fountain pen, and has the point of the magnet extended or retracted from a case by turning the end-knob. The strength of the magnet is controlled by the amount of extension. The probe is used for removing steel or iron particles from such places as electrical instruments, delicate mechanisms, and similar hard to reach places. General Scientific Equipment Co., 2700 W. Huntingdon St., Philadelphia 32, Pa.

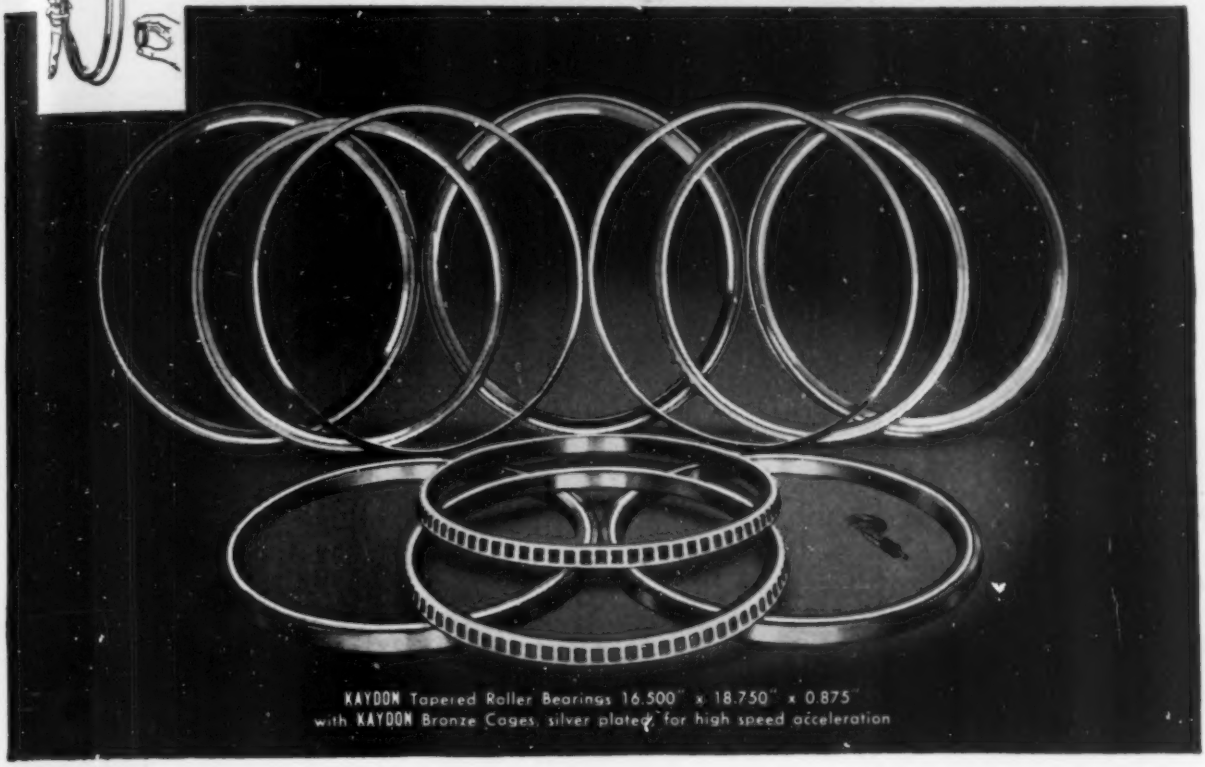
AN ANTI-ROTATION DEVICE, composed of a waved steel spring and a molded rubber ring has been developed to prevent spin and creep of the outer race of a floating bearing, and eliminate the damage resulting from this action. Available for use with most millimeter bearings, the device is equally effective in aircraft accessories, high-speed hand tools, electric motors, and other power tools. Bendix Aviation Corp., Scintilla Magneto Div., Sidney, N. Y.

A MERCURY SWITCH, for positive safety in hazardous, explosive locations, is mounted on a lever-operated armature, and is set in operation by a selector knob or push-button that inclines the armature, actuating the mercury switch. Designed for vertical panel mounting, the new mercury switch is a single-pole, with either single or double-throw action. Any possibility of a spark is eliminated. Tigerman Engineering Co., 4332 North Western Ave., Chicago 26, Ill.

A NEW THERMOSETTING RESIN COMPOUND requires only contact pressure for joining, and cures at room temperature. Known as A-6, it is suited to hard-to-bond metals, including the joining of aluminum to aluminum. Shear tests exceed 3,000 psi at room temperature and 2,500 psi at elevated temperatures. Contains no volatile solvent and does not shrink, swell, or creep. Armstrong Products Co., P. O. Box 1, Warsaw, Indiana.

Contact KAYDON Muskegon

FOR ALL TYPES OF BALL AND ROLLER BEARINGS: 4" BORE TO 120" OUTSIDE DIAMETER



KAYDON Tapered Roller Bearings 16.500" x 18.750" x 0.875"
with KAYDON Bronze Cages, silver plated for high speed acceleration

Safe Way to Reduce Weight

Look again at this thin section bearing. KAYDON bearings like these, designed with very thin section, are a boon to design engineers who recognize weight-reduction and greater precision as prime problems today.

KAYDON Thin-Section Tapered Roller, Straight Roller, and Ball Bearings are helping solve such problems. All types can be made unusually light in weight, and permit much more compact machine design.

Unique high precision techniques that hold to closest tolerances in bearings as large as 120 inches outside diameter, assure consistent accuracy in all types and sizes of KAYDON bearings and needle rollers.

★ ★ ★

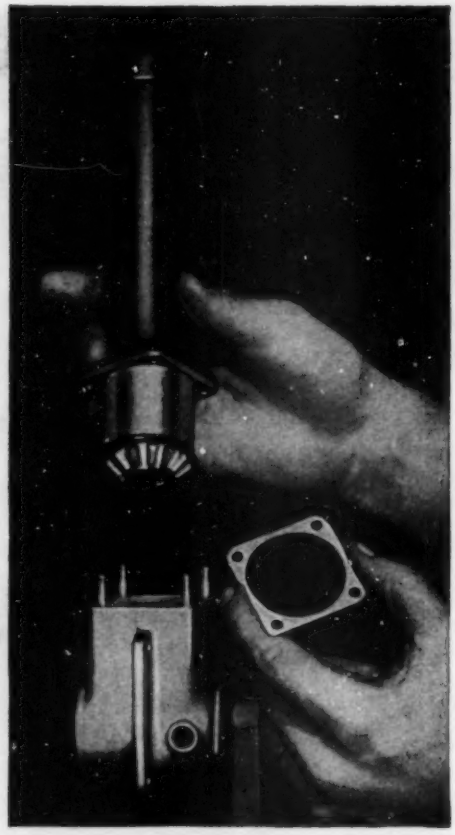
For your precision bearing requirements, contact KAYDON of Muskegon.

KAYDON Types of Standard and Special Bearings:
Spherical Roller • Taper Roller • Ball Radial • Ball Thrust
• Roller Radial • Roller Thrust • Bi-Angular Bearings

THE KAYDON ENGINEERING CORP.

MUSKEGON • MICHIGAN

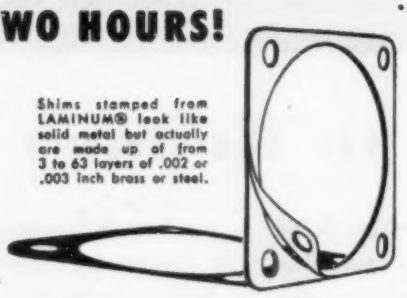
PRECISION BALL AND ROLLER BEARINGS



2 Seconds

CAN SAVE YOU TWO HOURS!

Shims stamped from LAMINUM® look like solid metal but actually are made up of from 3 to 63 layers of .002 or .003 inch brass or steel.



Adjusting bevel gear mesh with a laminated shim is a matter of two seconds to remove a lamination!

The shim in this case is made of LAMINUM®, our exclusive material. It is a "solid" unit built up of 16 layers of .002 brass. It peels quickly and easily. Each shim removed adjusts the bevel gear position by two thousandths.

You save time by easier machining tolerances on the housing; ***you save time*** by eliminating pesky assembly machining; ***you save*** by not tying up a machine intermittently. IT'S EASIER!

SEND FOR LITERATURE

LAMINATED SHIM COMPANY, INC.

SHIM HEADQUARTERS SINCE 1913

Check Our Stampings Division For Your Stamped Parts Requirements

1408 UNION STREET • GLENBROOK, CONNECTICUT

and pneumatic cylinders that permit standardization and savings in the total cost of a finished mechanism. Illustrated typical applications and data table on various tube sizes are included.

(40) NOMENCLATURE—The Aluminum Association, Booklet, 20 pp. Contains a glossary of terms for aluminum sheet and plate, and aluminum extruded and tubular products. Covers definitions of, and miscellaneous terms applicable to these products.

(41) PLASTIC MOLDINGS — Rostone Corp., Bulletin 100, 6 pp. Illustrates the many shapes molded from new stonelike, inorganic plastics, made in sizes weighing from one ounce to 7 pounds. Discusses general characteristics and electrical properties.

(42) LIQUID DRIVES—G. E. Nelson Co., Bulletin 6020, 8 pp. Has large cutaway view of: the traction sheave; the traction flexible coupling; and the traction hub mounted liquid drives. Also has complete specifications and engineering drawings showing installation arrangements for electric motors.

(43) SOLDERLESS POWER TERMINALS — Aircraft-Marine Products, Inc. Catalog, 16 pp. Designed for users of heavy power terminals and connectors, it describes the varieties of solderless power terminals and connectors, together with tables to aid in terminal selection. Also illustrated and described are hydraulic and pneumatic precision hand tools, and electric-hydraulic power tools.

(44) CONTROLLED VOLUME PUMPS—The Milton Roy Co., Bulletin 351, 24 pp. Contains complete details of air-operated controlled volume pumps and chemical feed systems, covering details of construction. Has cutaway views of the pumps and illustrated diagrams of controls and typical air-powered systems.

(45) NEOLYN RESINS—Hercules Powder Co., Booklet, 18 pp. Gives practical application data and starting formulations for the use of neolyn resins in adhesives, plastics, and organosols. Also contains technical information about the general properties of each of the seven resins in this series and performance characteristics.

(46) MEASUREMENT AND CONTROL INSTRUMENTS—Leeds & Northrup Co., Catalog ND46(1), 48 pp. Entitled, "Speedomax type G Instruments for measurement and control," it describes the increasing variety of uses of the instruments in industrial production and research. Also included are recorders for measuring pH, daylight illumination, electrolytic conductivity, and weight or mechanical loads. Contains illustrations of installation.

(47) NICKEL STEEL PROPERTIES—The International Nickel Co., Inc., Bulletin EU-93/20, 12 pp. Entitled, "Some Properties of low carbon 8½ percent Nickel Steel," it describes a ferritic steel that is resistant to the embrittling effects of low temperatures (—320 F) and can be welded and fabricated under the same conditions as engineering steels. Has 20 tables and charts giving mechanical properties and effects.

(48) TANK LINING — Metalweld Inc., Bulletin K, 4 pp. Discusses, illustrates and gives data on the application of flexible Koroseal to plating, tanks, racks, and vats. Materials handled include acid, bleaches, caustic, plating solutions, and many organics. Applied in thicknesses up to 3/32 in., and does not absorb liquids handled.

(49) POLARIZED MATERIALS—Pass & Seymour, Inc., Bulletin 2717, 4 pp. Has specifications and illustrations of two, three, and four wire receptacles and armoured caps used with polarized devices. Includes 3-wire grounding type outlets and caps, connectors and adapters, and other accessories.

(50) DIMENSIONAL CONTROL — Sheffield Corp., Booklet, 38 pp. Entitled, "Dimensional Control and Gaging Policy," it covers: gaging policy; tolerances; reference temperatures; gage specifications; ordnance practices; fixed gages; instruments; multiple semi-automatic and automatic gaging devices. Has illustrations and charts.

(51) SELENIUM RECTIFIER STACKS—General Electric, GET-2350, 28 pp. Describes the basic characteristics and the

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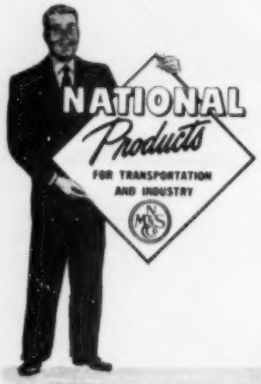

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applications of selenium rectifier stacks. Has charts, graphs, and tables illustrating the principles of rectification, and the characteristics, manufacture, circuit design, and application of selenium rectifiers.

(52) BELLOWS TEMPLATE KIT—The Clifford Mfg. Co., 5 pp. A new short cut for reproducing the many convolutions of metal bellows consists of a kit of bellows template, covering the 20 most popular bellows sizes. The selected template is placed under tracing paper, and reproduced.

(53) DOT TEENUTS—United-Carr Fastener Corp., Catalog E, 46 pp. Contains photos, engineering drawings, and complete specifications for the many types of teenuts produced for wood and metal. For metal, the types made are: round base, for both welding and riveting; the half-round base, for projection welding; lug type; slabbed base, for welding; rectangular base; and teenuts for steel tubing.

(54) AUTOMATIC PYROMETER—Illinois Testing Lab., Inc., Bulletin, 8 pp. Describes the pyrotac, a temperature control unit that automatically monitors up to 20 individual temperature points a minute, gives instant readings on temperature variations within any phase of heat processing. Colored diagrams show typical applications.

(55) AIR PUMPS—Eberbach Corp., Bulletin 300, 6 pp. Information on the air pressure or vacuum pumps designed for laboratory applications. Gives complete performance and size specifications, suggested uses, and illustrated descriptions of unmounted and motor-mounted models.

(56) STAINLESS STEELS—Armco Steel Corp., Bulletin, 46 pp. Discusses the fundamentals of stainless steels, and the types of stainless steels including a complete chemical analysis of each. Types covered are: the chromium-nickel; ferritic chromium, the martensitic chromium; and the precipitation-hardening types. Also gives other properties, and details on fabrication, blackening, and electroplating.

(57) UNIVALVES—Edward Valves Inc., Catalog 12-G1, 8 pp. Describes the univalve integral seat all-purpose forged steel valves rated for 1,500 and 2,500 lb. Has complete material specifications and detailed chemical analysis. Also cutaway view and photo giving step-by-step disassembly procedures.

(58) ACME SCREW THREADS—ASME, ASA B1.5-1952, 41 pp. Also Stub Acme Screw Threads, ASA B1.8-1952, 21 pp. Information compiled by the Sectional Committee on Standardization and Unification of Screw Threads, B1, and approved by the American Standards. Covers the general purpose and stub Acme threads; centralizing acme threads; gages for acme and stub acme threads; tolerances and other points. Includes many tables and drawings.

(59) AMERICAN STANDARDS PRICE LIST—American Standards Association, 32 pp. Contains prices for products used in various industries. Included are: civil engineering and construction; mechanical engineering; electrical engineering; automotive; ferrous materials and metallurgy; nonferrous materials and metallurgy; rubber; chemical industry; textile industry; mining; wood industry; pulp and paper industry; photography; office equipment and supplies; and miscellaneous groups.

(60) PLSTIC FITTINGS—American Agile Corp., Catalog, 12 pp. Describes the complete line of corrosion resistant plastic pipe, tubing, ducting, and fittings. Physical properties of pipe given, as well as complete specifications and illustrations for all types of tubing, ducting, and fittings.

(61) INDEX OF LITERATURE—Minneapolis-Honeywell Regulator Co., Bulletin, 100-A, 20 pp. Consists of both a numerical listing and an alphabetical cross index for specification sheets, instrumentation data sheets, catalogs, and other literature. Included are articles from "Instrumentation," the manufacturer's quarterly publication.

(62) TABLETTING PRESSES—F. J. Stokes Machine Co., Catalog 800, Illustrates and describes a complete line of tabletting presses used for pharmaceuti-

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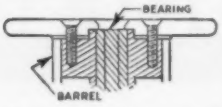

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cal, powder metal, general industrial and plastic preform production. All models of single-punch, rotary mechanical, and hydraulic presses are included.

(63) INDUSTRIAL MAGNIFIERS — Bausch & Lomb Optical Co., Bulletin I-67, 24 pp. Entitled, "Industrial Magnifiers—How to Choose and Use Them," it outlines the optical principles of magnifiers, describes basic types, and gives a magnifier selector chart and glossary. Contains more than 50 photographs and diagrams, and gives specifications for the 75 magnifiers made for all uses.

(64) CHAIN DRIVES & CONVEYORS — Chain Belt Co., Bulletin 51-7, 32 pp. Called, "Installation, Operation, and Maintenance of Chain Drives and Conveyors," it gives helpful hints, aided by many illustrations and drawings, in the care of chain drives and conveyors. Covers: installation and operation; care of sprockets; lubrication; inspection and storage; adjustment and repair.

(65) SPLIT SLEEVE TAGGING—Duramark Inc., Bulletin. 4 pp. Facts on tags used as cable markers, name plates, inventory checks, pipe markers, tool checks, wire markers, and others. Lamination protected. Illustrations show method of installation.

(66) INDUSTRIAL ENAMEL — Erie Enameling Co., Booklet, 16 pp. Entitled, "Porcelain Enamel to Handle the Tough Jobs," it contains sections on the types of porcelain enamel, information on physical characteristics, and list of applications. Also has a section on the use of color in industrial enamel, and rules for designing for porcelain enamel.

(67) POWER PIPING DESIGN—Taylor Forge & Pipe Works, Bulletin 515A, 8 pp. Entitled, "How to Use Schedule Numbers in Power Piping Design," the author explains the relation of the schedule number system to the code formulas for determining the wall thickness of power piping. Included are large graphs for selecting pipe wall thickness.

(68) DIFFERENTIAL TRANSFORMERS —Automatic Temperature Control Co., Inc., Bulletin R-31, 12 pp. Explains in detail the characteristics of linear transducers and their varied use. Containing many illustrations, it includes all the various types of indicators, recorders, pressure transmitters, control relays, servo mechanisms, load cells, and other industrial instruments.

(69) SUMP PUMPS — Warren Steam Pump Co., Bulletin WQ-220, 8 pp. Description and illustrations of the improved models of the types VS and VN sump pumps. These pumps are available in wet and dry pit types, and will handle clear liquids, and liquids containing solids. Engineering drawings, and complete specifications.

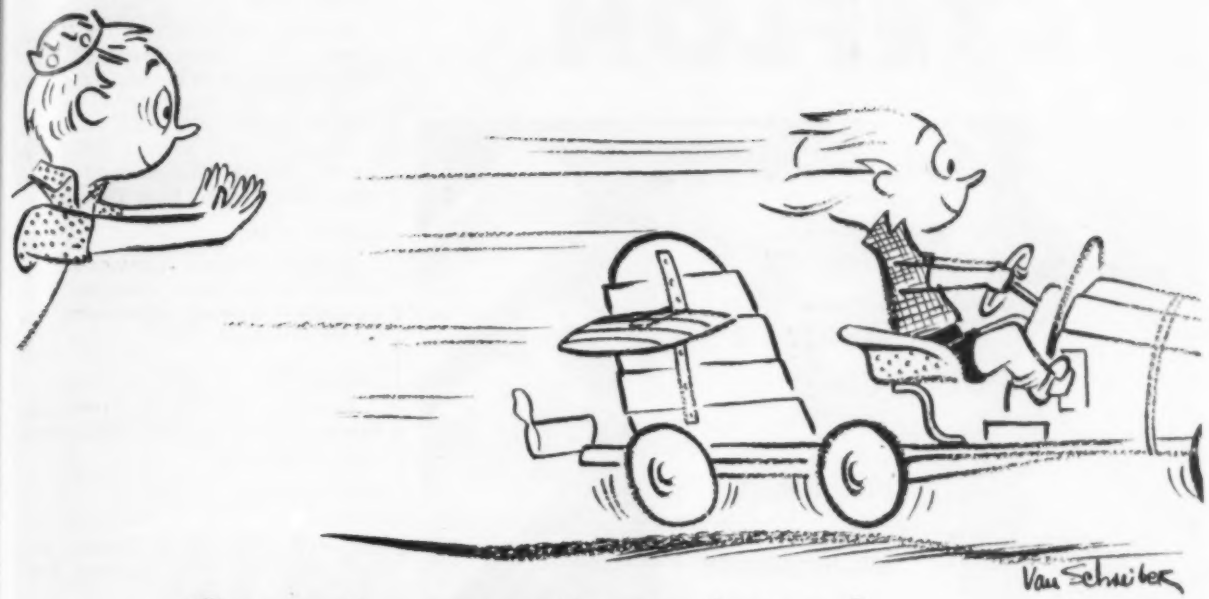
(70) WHAT'S A SILICONE—Dow Corning Corp., Booklet, 32 pp. This question has been asked many times, with a different and partly correct answer given each time. As an unknown quantity can only be described in terms of what it does, the booklet was written on this plane.

(71) REINFLASTICS — Russell Reinforced Plastics Corp., Booklet, 16 pp. Describes a new low pressure laminate of reinforced fiberglas, nylon, or other materials. Contains many illustrations showing production of all types of molded parts, and suggests many applications.

(72) AIRBORNE MOUNTING BASES—T. R. Finn & Co., Inc., Catalog MB-110, 4 pp. Describes the airborne electronic mounting bases; vibration isolators for these bases; type M shock mounts to signal corps specifications; and fire control shock mounts. Explanatory diagrams and complete specifications given.

(73) TACHOMETERS — Metron Instrument Co., Data Sheet T4, 4 pp. Describes the principle of operation of hand, portable, and fixed installation tachometers. Contains simplified circuit diagrams, and describes the basic circuit in detail. Has illustrations on many models.

(74) HYDRAULIC COMPONENTS—Racine Tool & Machine Co., Catalog P-10-D, 18 pp. Contains colored cutaway views of pumps, valves, pressure boosters, special valves, pumps, and reservoir units. Also has piping diagrams and complete description of operation.



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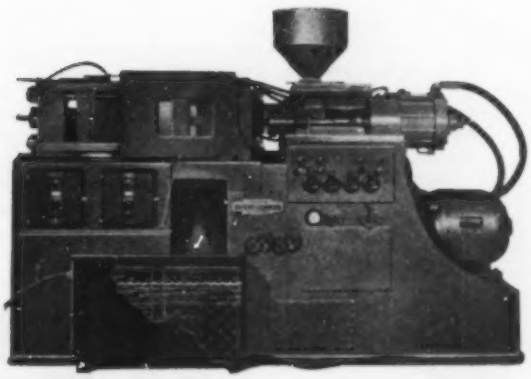

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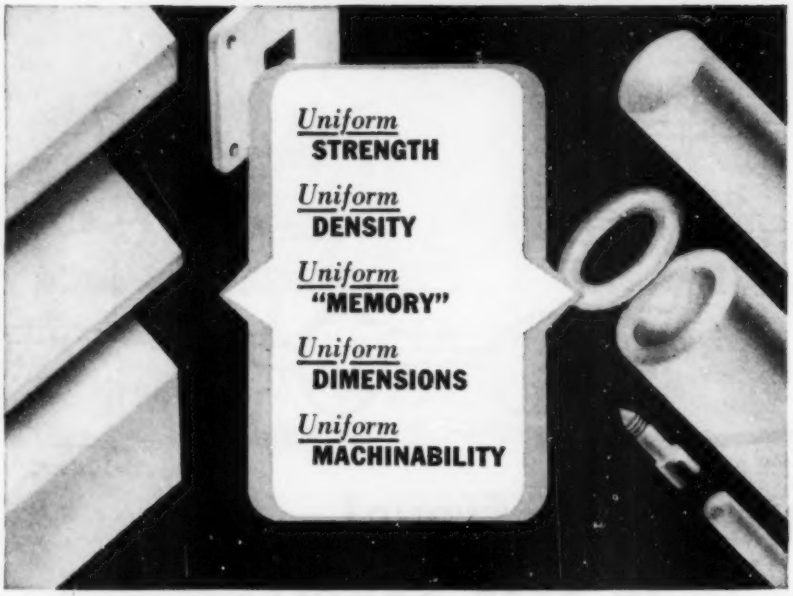

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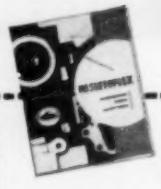

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MEETINGS

August 11-13

SOCIETY OF AUTOMOTIVE ENGINEERS—West Coast Meeting. Fairmont Hotel, San Francisco, Calif.

August 12-16

PHOTOGRAPHIC SOCIETY OF AMERICA—Technical Division Meetings. Hotel New Yorker, New York, N. Y.

August 20-28

INTERNATIONAL CONGRESS ON THEORETICAL AND APPLIED MECHANICS — Istanbul University, Istanbul, Turkey.

August 27-29

WESTERN ELECTRONIC SHOW AND CONVENTION—Municipal Auditorium Long Beach, Calif.

September 4-5

NATIONAL CONFERENCE ON INDUSTRIAL HYDRAULICS—Eighth Annual Meeting, Hotel Sherman, Chicago, Ill.

September 8-10

NATIONAL STANDARDIZATION CONFERENCE, Sponsored by American Standards Association—Museum of Science and Industry, Chicago.

September 8-11

AMERICAN SOCIETY OF MECHANICAL ENGINEERS—Fall Meeting, Sheraton Hotel, Chicago.

September 9-11

SOCIETY OF AUTOMATIVE ENGINEERS — Tractor Meeting, Hotel Schroeder, Milwaukee, Wis.

September 9-13

NATIONAL CHEMICAL EXPOSITION —Chicago Coliseum, Chicago, Ill.

September 10-12

PORCELAIN ENAMEL INSTITUTE—Annual Shop Practice Forum, University of Illinois, Urbana, Ill.

September 11-14

PACKAGING MACHINERY MANUFACTURERS INSTITUTE—Annual Meeting. The Homestead, Hot Springs, Va.

September 29-October 1

NATIONAL ELECTRONICS CONFERENCE—Eighth Annual Conference, Sherman Hotel, Chicago, Ill.

September 30-October 3

ASSOCIATION OF IRON AND STEEL ENGINEERS—Annual Convention and Iron and Steel Exposition, Cleveland Public Auditorium, Cleveland, Ohio.

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Sans, Souci

Ad Libbing by the Editor

There are many reasons why politically appointed commissions dealing with engineering matters are too often composed of men who are anything but engineers. After all, party affiliation and the control of votes is usually a prime consideration in making appointments to such a committee. Many men in public office will heartily disagree with this point of view and it is true that they will be able to cite quite a few commissions that were appointed without political considerations, at least so they will claim. And it is to be admitted that a commission that is politically appointed is not necessarily a bad commission.

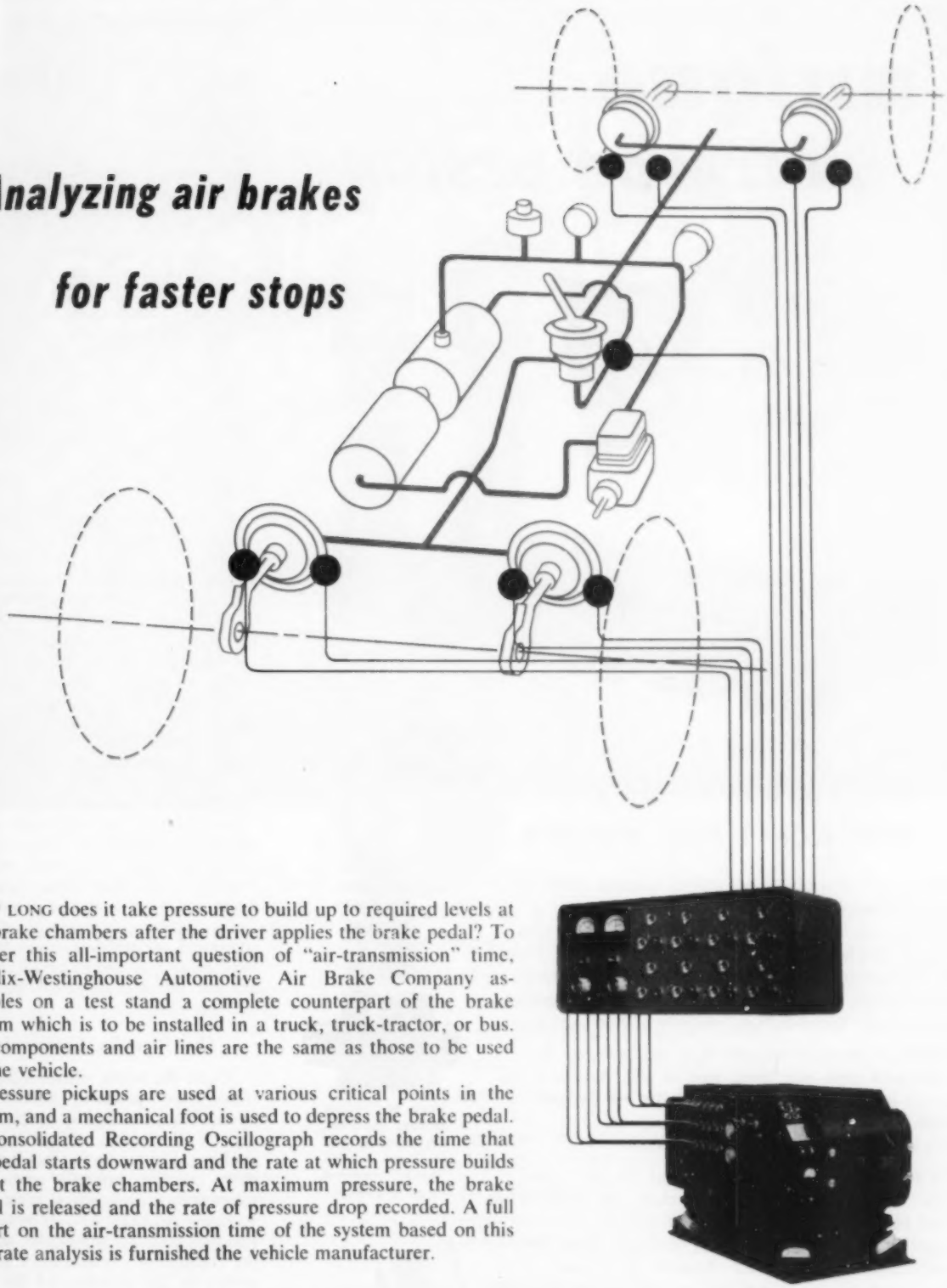
In any event, my mind was focused on a type of politically appointed commission commonly found in our towns and cities. I have reference to the sanitation commission, plumbing code commission or whatever you may wish to call it. Apparently, the common practice is to appoint the outstanding local plumbers to the plumbing commission or committee. This is very nice, especially for the plumbers.

A few weeks ago I was reading an Ohio newspaper which told the story of a good patriotic citizen who wanted to do his own plumbing for his home. As I got the story, he "roughed out" the plumbing and then applied for inspection, but the inspector did not come. He applied again and again but even after several months there was no inspector forthcoming. In desperation, this poor John Q. Citizen covered up the "rough" plumbing. That is, he put down his cellar floor and plastered his walls. Maybe he concluded that the plumbing inspector and the committee had forgotten all about it. But the inspector had not forgotten. It appears that he just wanted Mr. John Q. Citizen to do exactly what he did. After the cement had hardened and the walls were all nicely finished off, Mr. Plumbing Inspector came along and demanded to see the pipes. By that time John Q. Citizen was in a rage. He told the inspector he had given him all the opportunity in the world to inspect the plumbing, and so on.

The Court Decided

As can be expected, the City Plumbing Inspector resorted to court action, which didn't cost him a penny because the taxpayers paid for it. The judge

Analyzing air brakes for faster stops



How long does it take pressure to build up to required levels at the brake chambers after the driver applies the brake pedal? To answer this all-important question of "air-transmission" time, Bendix-Westinghouse Automotive Air Brake Company assembles on a test stand a complete counterpart of the brake system which is to be installed in a truck, truck-tractor, or bus. All components and air lines are the same as those to be used on the vehicle.

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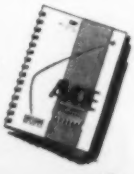
View of plating station. Six bearings are positioned in hard rubber "stacks" mounted on plating head.



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simply carried out the letter of the law and Mr. John Q. Citizen was guilty. The court wouldn't even give John Q. Citizen the chance to change the plumbing to conform to the code. The judge insisted he had to hire a licensed plumber to do the job. And thus the sordid story goes along.

One may conclude that the plumbing inspector took John Q. Citizen for a beautiful "ride." He wanted to fix poor John so he would never again attempt to do his own plumbing. Now John might have been a plumber far superior to the best in town. His work might have conformed to every bit of code. But perhaps the plumbing inspector wasn't interested in that at all. Perhaps he just wanted to be sure that John would have to hire a plumber to do the job.

Ironically, in this particular code were a lot of requirements that were usually ignored by the plumbing inspector because they were obsolete. The whole code was an old fashioned mess and nothing was ever done to bring it up to date. Nor was there reported any attempt on the part of the plumbing inspector or the plumbing committee to bring it up to date. The more confused the code the more opportunity to make decisions to suit.

Technical problems relating to plumbing, heating and ventilation are getting quite complex. Many of the problems are fundamentally engineering problems, but engineers are not usually appointed to draw up the plumbing code. I wonder why the heating and ventilating engineers never see to it that the membership of a plumbing commission shall be composed of qualified engineers who have no special axe to grind and who are not tempted to abuse the power of their office.

The Turnpike Commission

Maybe the whole situation described above exists primarily because engineers do not rate highly in the estimation of the public. That might be readily explained by the fact that engineers are not generally given credit when they accomplish a great public service. Anyone who traverses the Pennsylvania Turnpike and stops at the "Midpoint" restaurant can see a picture of the members of the Turnpike Commission, which commission is credited with having created and brought into being the great Pennsylvania Turnpike. Frankly I do not know exactly what these men did to bring the Turnpike into being. There is no mention made in the picture that they had anything to do with the design and the building of the Turnpike. Presumably, after the Turnpike Com-

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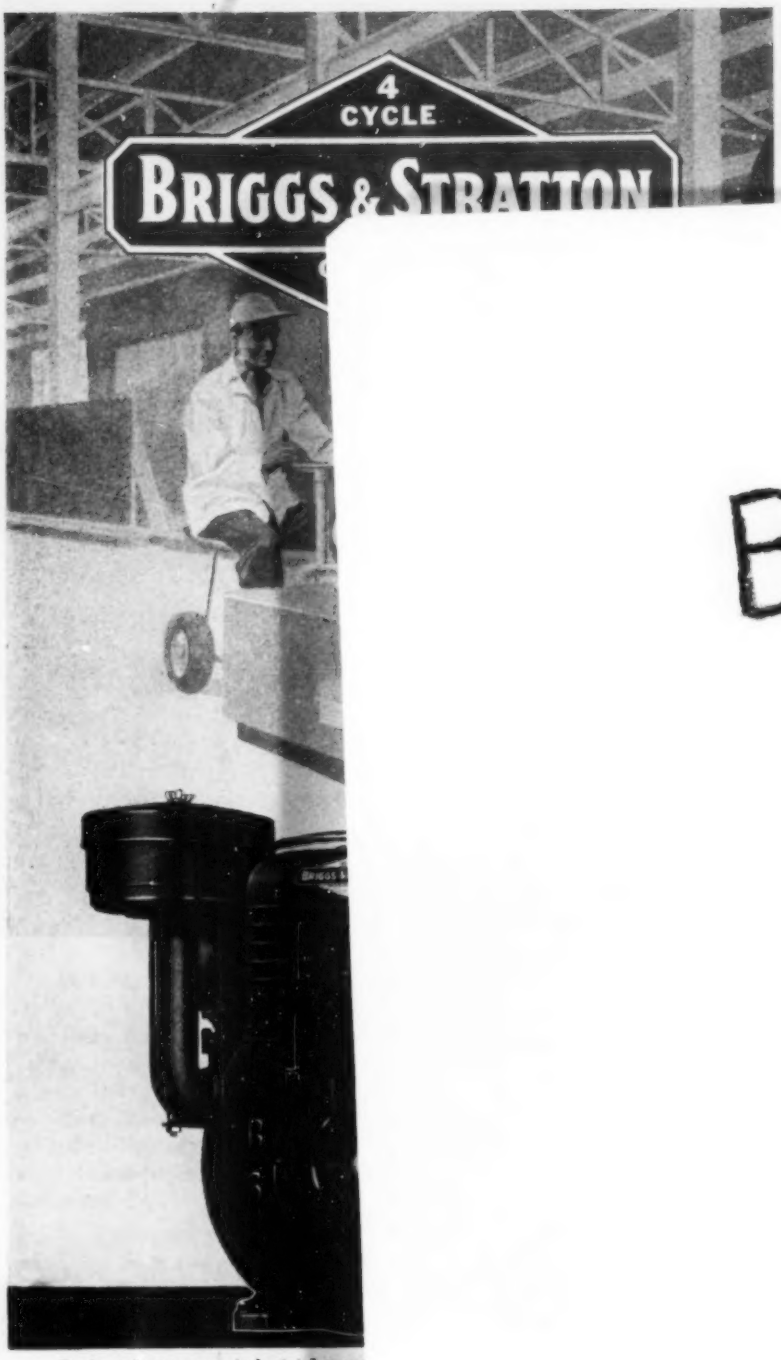

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Sans, Souci ..... continued

mission was appointed the Turnpike automatically came into existence, without design or building.

Of course there will be many engineers who will consider it hel

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—G. F. N

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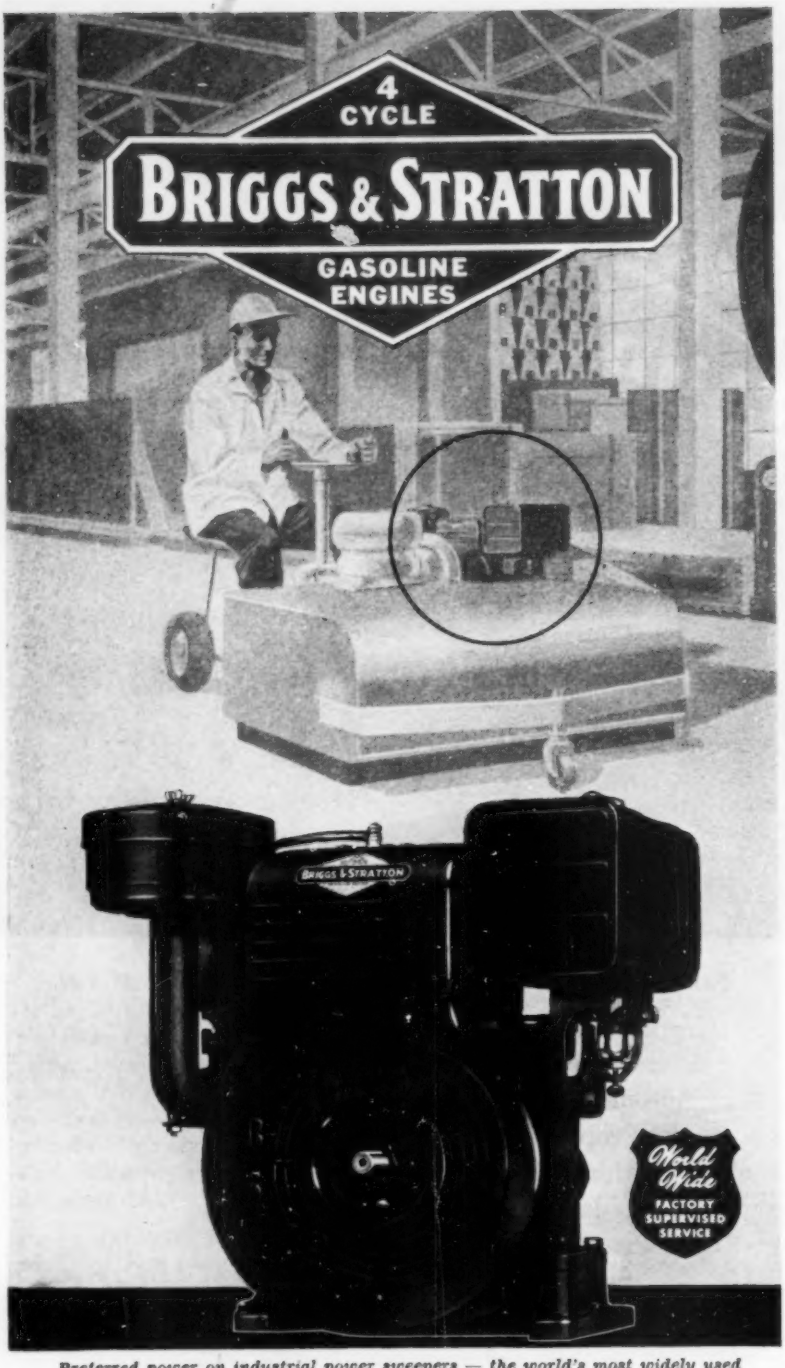

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Time-tested, compact, powerful, reliable — Briggs & Stratton single-cylinder, 4-cycle, air-cooled gasoline engines are made by the world's largest builder of engines, and backed by the world's largest service organization of its kind. Briggs & Stratton Corporation, Milwaukee 1, Wisconsin, U.S.A.

In the automotive field Briggs & Stratton is the recognized leader and world's largest producer of locks, keys and related equipment.

mission was appointed the Turnpike automatically came into existence, without design or building.

Of course there will be many engineers who will consider it below their personal dignity to "blow their own horns". That is false modesty. Personal dignity and public recognition go hand in hand.

One of the arguments used by manufacturing companies against revealing the names of the engineers who are to be credited with a given development is that it might cause a tremendous amount of jealousy within the organization. Furthermore, it is claimed, and it is generally true, that there are always a number of engineers involved in any given development. Often it is extremely difficult to properly allocate credit for a given development. The same can be said of almost every undertaking.

It certainly would not be out of line for a company to give the name of the chief engineer and the names of several of his direct assistants who are to be credited with a given design. There is one commercial argument against it in that such publicity would give the individuals added prestige and might well open doors for them to obtain a better job elsewhere. Perhaps this is true in a few rare cases, but the fact is that the competitors soon find out who accomplished what.

The other side of the picture is that the prestige and enthusiasm which results from public recognition of those who are to be credited with a given development is tremendous. It is a well established psychological fact that the human being attaches a terrific value to receiving credit for that which he accomplishes. A company that tries to hide its engineers from public view and keep their accomplishments and qualities a secret soon finds that there is little or no esprit de corps in their engineering department, which situation is reflected in the designs produced.

From my office window in the towering green building on Forty-Second Street I just saw the United States dock at the end of her record breaking voyage. William F. Gibbs of the firm of Gibbs and Cox is credited with being the designer of that ship.

Mr. W. F. Gibbs is one of the country's greatest naval architects. Under his leadership the great vessel was designed. Next month I'll tell you more about it and about the men who designed the hull, the propulsion machinery and other sections of this wonderful new queen of the seas.

—G. F. N

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Recently, The Consolidated Edison Company (in New York City) faced this problem: It had to produce a direct-process print from each one of more than ten thousand Brooklyn Underground Record Maps, showing the distribution system of electric service.

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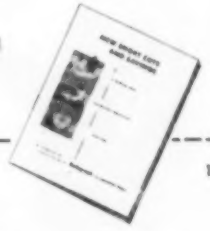

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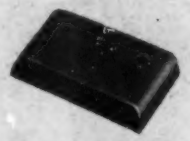

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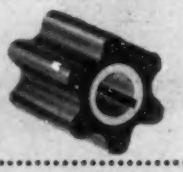

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ENGINEERING ABSTRACTS

Hard Chromium Plate and Bright Plating of Steel Or Die Castings

Abstracted from "Hard Chromium Plate and Bright Plating of Steel or Die Castings" by Allen G. Gray, Consulting Editor to Metal Progress. Metal Progress, June 1952.

IN ADDITION TO ITS EYE APPEAL, electrodeposited chromium has valuable properties in a number of strictly engineering uses. This type of chromium plate is generally termed "hard chromium". It is, indeed, harder than any other commercially plated metal. The life of certain tools can be prolonged by chromium plating to proper thickness. In addition, it has a low coefficient of friction and nongalling properties, together with good resistance to corrosion at both ordinary and elevated temperatures.

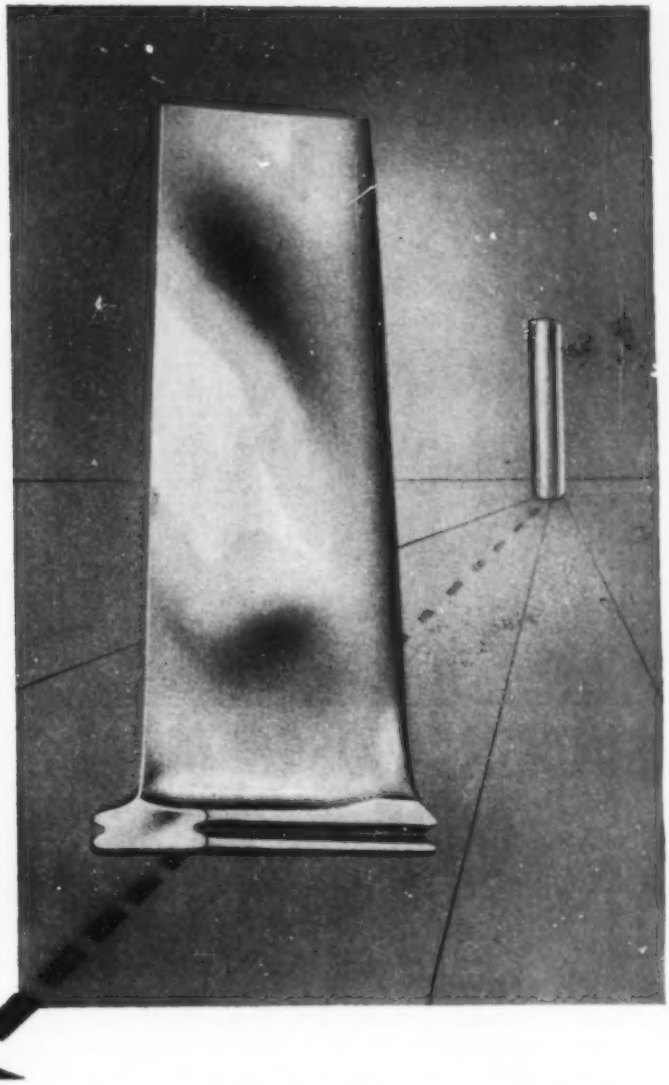
Wearing surfaces can frequently be improved by chromium plating. Spindles, shafts, pistons and machine parts subject to wear or scuffing were at one time plated principally for salvage and resue after being worn down below limits. Often these salvaged parts outlasted the originals, and thus reduced maintenance requirements and conserved labor and strategic materials. The low coefficient of friction of chromium against other metals is an important factor in its long life on shafting, piston rings, internal combustion engine cylinders and similar applications.

Chromium plating may also be used to salvage new parts that are undersize due to errors in machining or grinding.

Properties of Chromium Plate

Chromium is rather unique among electrodeposits because of the important bearing its structure has upon its uses and performance. Actually, several variations in structure and physical properties are possible by proper adjustment of the plating conditions and post-plating treatments. Structural changes taking place on heating chromium plate are those normal for a highly stressed, fined-grained metal.

The endurance of aircraft steels (SAE X-4130 and 6130) was found to be reduced by chromium plating. While the decrease in the endurance limit of the normalized steel was gen-



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As primary suppliers of forged turbine and compressor blades to the aircraft industry, UTICA is going at top speed. But that *alone* is not good enough – not for *this* race.

So we at UTICA examine our methods, study them, modify them, improve them. We seek always to speed, shorten and eliminate steps between bar stock and blade.

The job must be done today, for today is soon tomorrow. Tomorrow's method will not wait until the day after – not at UTICA.

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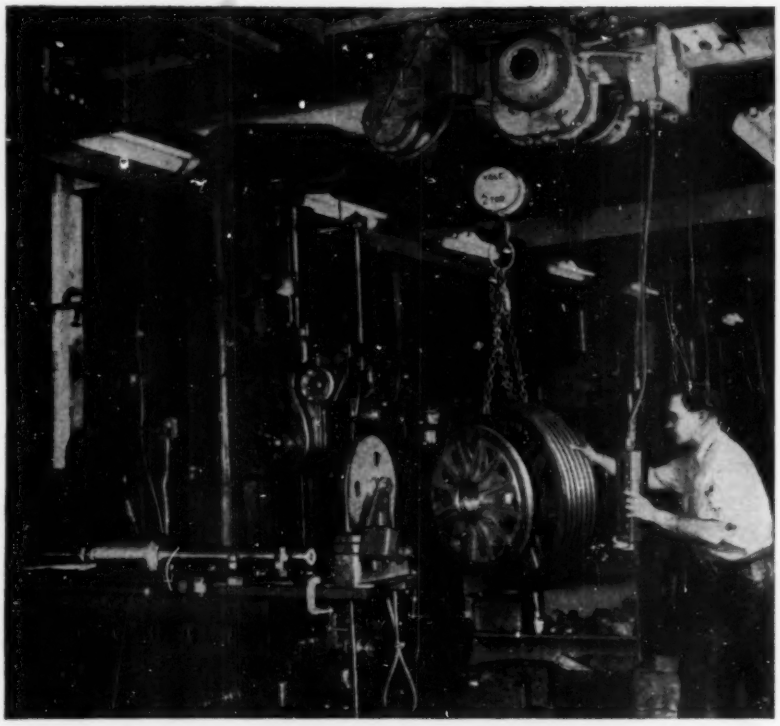

HANDLING COSTS CUT by YALE CABLE KING HOISTS

— with Star-Kimble motors on hoist and trolley

ENTHUSIASTIC users of Yale Cable King Hoists report that fast, accurate, reliable handling of heavy loads result in substantial savings in time and costs.

Built for continuous service around the clock, and designed for operation outdoors as well as in, these hoists call for rugged components. Hence Yale & Towne turned to Star-Kimble for the hoist and trolley motors — and Star-Kimble engineers came up with special designs that meet every Cable King requirement.

The 3-phase squirrel-cage hoist motor operates under severe hoisting conditions without overheating — provides plenty of reserve capacity for short-time overloads. Dust-tight, weatherproof construction permits outdoor operation.

Trolley motor is a Star-Kimble Brakemotor that spots the load accurately — no need for time-consuming inching. Adjustable braking torque brings the load to quick, smooth stops.

This is typical of the many ways in which Star-Kimble engineering skill has benefited the designers and users of all sorts of motor-driven equipment.

For information on design and service features of Star-Kimble Squirrel-Cage Motors, write for Bulletin B-211; for Brakemotors, Bulletin B-501-A.

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MOTOR DIVISION

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erally small, the reduction by plating was greater in the hardened steels. The minimum endurance limit of any group of plated specimens was 75% that of the unplated steel. (Figures for most sets of tests specimens ranged from 83 to 95.5%.) The endurance limit of specimens heated after plating reached maximum value for baking temperature between 190 and 300 C. (375 and 575°).

In Bureau of Standards studies reported in *Journal of Research* in 1951 the effect of chromium plating on the plastic deformation of SAE 4130 steel by ordinary tensile, tensile impact, bending and crushing tests were evaluated. Test pieces were plated in an electrolyte containing 250 g/1. of chromic acid and 2.5 g/1. of sulphuric acid at 55°C., using a current density of 350 amp/sq. ft.

The most pronounced effect of chromium plating was to reduce the plastic deformation prior to fracture in all types of tests except the tensile impact. The reduction of elongation in tensile tests was particularly noticeable. Tensile and yield strengths of plated steel decreased as the thickness of the chromium was increased from 0.001 to 0.015 in.; steel plated 0.015 in. thick showed 91% or more of the corresponding properties of the unplated steel. Baking at 200 to 400°C. (390 to 750°F.) for 6 to 8 hr. substantially increased the plastic deformation before fracture.

Heat treatment is important to a number of applications of chromium plating, notably plated tools. Additional life ranging from two to ten times the normal life of unplated tools has been obtained when they are properly plated and heat treated. Good results have been obtained with cutting tools by heat treating at 600°C. (1100°F., or higher, depending on the steel) to stress-relieve prior to chromium plating. After plating for an average period of about 5 min., the plated tool is again stress-relieved by heating in air or oil at 350°F. for 1 to 3 hours.

A special tyype of chromium plate, known as "porous chromium", is produced by selective etching of surface cracks to give an oil retentive surface. Thus, the poor wetting characteristics of chromium plate are counteracted, while the good properties of the plate are unimpaired. So-called "Locontraction" chromium plate is deposited at elevated temperatures, and is described as having relatively few cracks and exceptional resistance to hot corrosive gases. Another variety is a high-speed process used for steel plant maintenance. Characteristic are high current densities and a chronic acid bath con-

Machine tool idea pool

In designing machine tools, as in planning countless other products, OSTUCO Steel Tubing provides an endless pool of practical ideas because of its *unlimited adaptability*. Collets, chucks, spacers, spindles, bearings, shafts, ferrules, and handles are but a few of the applications.

By varying the radius of a bend, the length of a taper, the dimension of an upset, etc., an old design can be improved or a new one created. By combining such operations, a part can be made to serve several functions, thus simplifying design. Parts may even be fabricated or forged beyond recognition as a tube section.

Whether you design machine tools or products of a distinctly different nature, you will want to investigate the many quality-improving, cost-reducing features of OSTUCO Tubing. We cannot always promise early delivery estimates on new civilian orders, because of military demands, but it will pay you to consult our experienced engineers about OSTUCO Tubing when redesigning your products to meet future competition.

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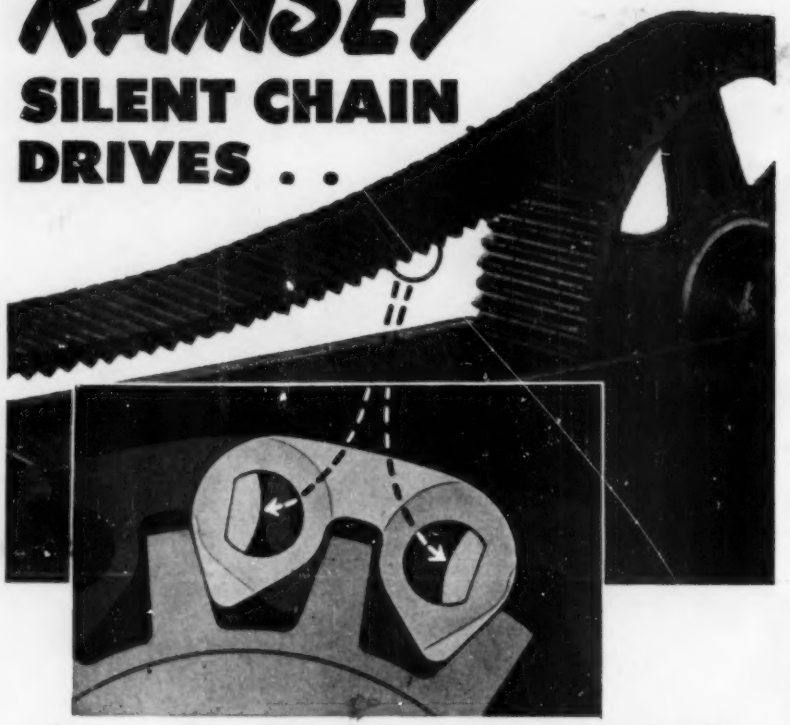

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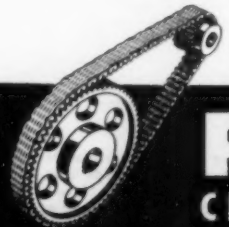

SILENT CHAIN DRIVES – FLEXIBLE COUPLINGS

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taining a high concentration of sulphate radical at high temperature.

Decorative Uses

The pleasing blue-white color, superior hardness, and the useful oxidation and tarnish resistance of chromium plate are the main reasons for its wide application in decorative uses. The chromium is generally applied as a thin final deposit over a much heavier bright or buffed nickel plate. Copper plating is widely used on steel and die casting as an undercoating for the nickel-chromium finish.

As a substitute finish for decorative chromium, zinc plate followed by a chromate bright dip lacquer is being used on steel and on zinc-base die castings. However, the color of this finish differs somewhat from that of chromium.

Chromium plate normally has a very thin transparent oxide film on its surface, which is so stable, tenacious, refractory and self-heating that it protects the metal underneath from further oxidation. The plate remains bright at temperatures up to 500°F., but on prolonged heating in air at higher temperatures the oxide film grows in thickness and darkens. The chromium oxide is also a satisfactory protection against sulphides which tarnish silver, copper or nickel at normal atmospheric temperatures.

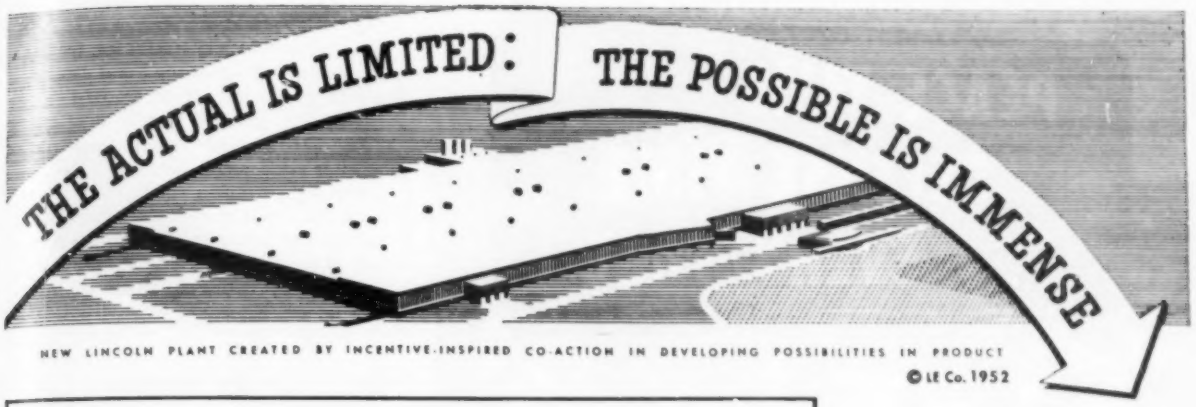
In thicknesses greater than about 0.0005 to 0.001 in., chromium plate protects against many other types of corrosive environments. Although it is attacked by mineral acids and certain reducing solutions, it is strongly resistant to nitric acid, which heals the protective oxide film. The deposit should be sufficiently thick to insure that the cracks in the plate are not continuous to the basic metal.

In general, at ordinary temperatures chromium plate of proper thickness may be applied in the same types of service as the high-chromium-stainless steels. Substitution depends to a considerable extent on the physical properties required of the basis metal.

Chromium-Plated Die Castings

Corrosion tests indicate that at least 0.002 in. of copper and nickel was necessary to provide adequate protection of aluminum-base die castings against outdoor corrosion for one year in the severe locations. On zinc-base die casting, 0.00125 in. gave fair protection, and the additional protection produced by going to 0.002 in. was comparatively small. There was little correlation between salt-spray results and exposure tests.

Exposure tests showed that each



NEW LINCOLN PLANT CREATED BY INCENTIVE-INSPIRED CO-ACTION IN DEVELOPING POSSIBILITIES IN PRODUCT

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WELDED STEEL SIMPLIFIES CONSTRUCTION IMPROVES PERFORMANCE, CUTS COST 33%

By **Russell M. Roberts,** Chief Engineer,
Parks Woodworking Machine Company, Cincinnati, Ohio

Changing over our band saw frame to welded steel design has simplified many production problems while cutting costs by one third.

The original cast construction (Fig. 1) called for machining a complicated casting on which foundry rejections were common. The present welded steel design utilizes simple square tubing, sawed to size, clamped in a plain fixture and butt welded. The efficient use of steel has cut weight by 37% while increasing strength and rigidity.

An added benefit, made possible with welded design, now permits independent leveling of the work table that formerly could be accomplished only through a major adjustment of the frame itself.

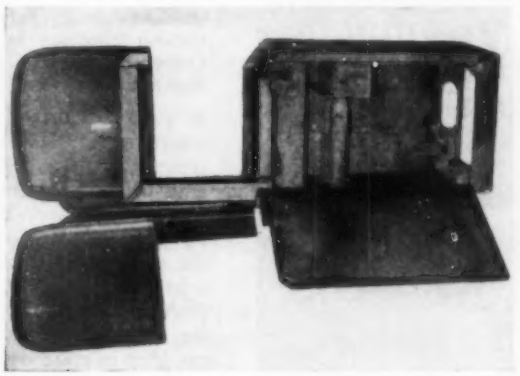

Fig. 4—All Welded Steel Frame *for the Parks Woodworking Machine Co., Cincinnati, Ohio. Sides are brake formed from 12 gauge metal.*

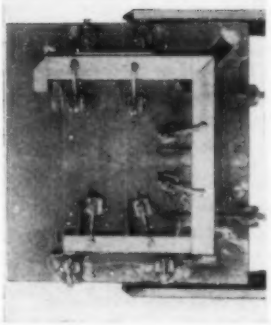

Fig. 3—Simple Jig *for welding square steel tubing components consists of clamps and locating pads.*

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PROPER DESIGN IN WELDED STEEL ALWAYS IMPROVES PRODUCT, LOWERS COST

Fig. 1—Original Construction—*Machine bracket formerly weighed 56 pounds, was difficult to cast, high cost incurred from excessive rejects.*

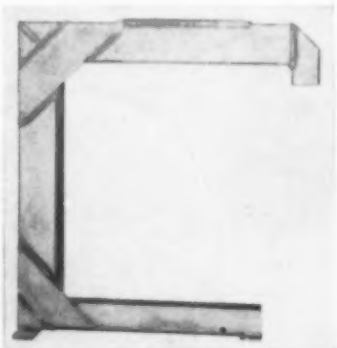

Fig. 2—Welded Steel Design *is stronger, more rigid yet weighs only 35 pounds. Weldment costs 33% less than original casting. Eliminates considerable time in machining and assembly.*

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base metal had a characteristic type of corrosion. Magnesium was deeply pitted, particularly at the seacoast. The plated zinc control panels were covered with a much larger number of smaller sized pits. Aluminum showed spreading corrosion at the interface in both industrial and seacoast exposures. In the last analysis, the corrosion of the plated zinc was not as objectionable as that of the aluminum or magnesium die castings.

Better Design Permits Cheaper Stampings

Abstracted from "Better Design Permits Cheaper Stampings" by Frederico Strasser, Consultant, Santiago, Chile. Iron Age, May 8, 1952

A PART DESIGNED ESPECIALLY FOR MANUFACTURE ON A PRESS will be cheaper than one designed without regard to the production process to be used. Essential requirements of strength and shape must be met, but the thoughtless designer can lay out a part which will be difficult and expensive to form. Or, while retaining the essential part characteristics, he can keep in mind design details which will make the part easier to form. There are many important points to keep in minde regarding stock cost of materials. So it is necessary to avoid intricacy, pierced holes, and special operations.

The chief cost factor of stampings is usually the waste of stock. In the production of blanks cut from strips, the remaining skeleton is composed of bridges between adjacent blank openings and between blank openings and strip edge. It is often possible to eliminate one or both kinds of bridges, obtaining partially or totally scrapless blank design.

Components with sides at right angle are very easily blanked by scrapless or semi-scrapless dies. Parts can be produced by this method with sides not at right angles if the corresponding sides match in shape.

Another way for economizing material consists in utilizing the unavoidable waste, either blanking from the same strip different figures whose shape complement each other or employing the slug produced by the punching or piercing operation for further uses. The production of lamination dies for electrical motors is a typical instance. As shown in Fig. 1, while producing the stator rings the central slug is utilized directly for the rotors of the same motor.

When the precision requirements are not too high and shape allows, cropping dies should be employed.

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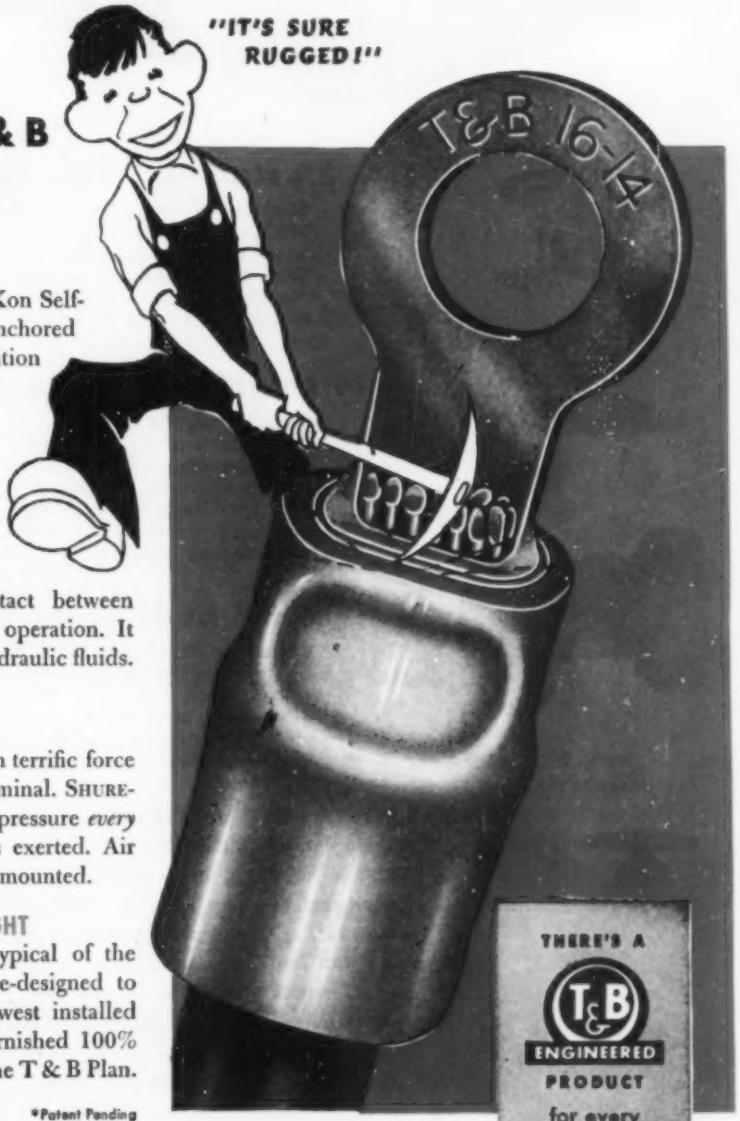

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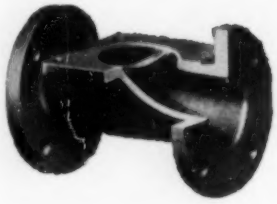
Diaphragms, the heart of Hills-McCanna Valves, are offered in the widest choice to best suit your individual needs; 5 types of rubber, 3 of Neoprene plus Hycar, butyl, Tygon, Compar, special polyethylene and Kel-F.



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By offering such a broad selection of operators, diaphragms and bodies, Hills-McCanna is able to furnish so many standard combinations that the user is in the position of being able, in most cases, to find the exact valve that best fits his individual requirements. There is virtually never any need to adapt to your service a valve developed for someone else's needs.

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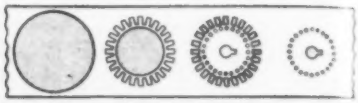


FIG. 1—When stamping out electric motor stator laminations, waste is reduced as shown by utilizing the center blank for motor rotor laminations.

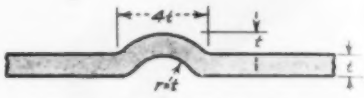


FIG. 2—Ribs often add strength to parts to permit use of thinner stock than otherwise. Recommended dimensions for ribs, based on stock thickness, are shown.

There is no lateral waste, because the strip has the same width as the part to be produced. The only scrap created is that which is cut by the cropping punch. Even this waste is avoided by shearing dies, but these can be employed only when both ends of the blanks have matching contours.

There is another way to save stock: Through material of lighter gage. Very often the same strength and rigidity can be obtained from thinner metal reinforced by ribs, flanges, or curling. Ribs are best dimensioned in proportion to stock-thickness, according to Fig. 2 which gives minimum values. Ribs should not be made with the grain, but across it, like simple bends are made.

Complicated Blanks Waste Stock

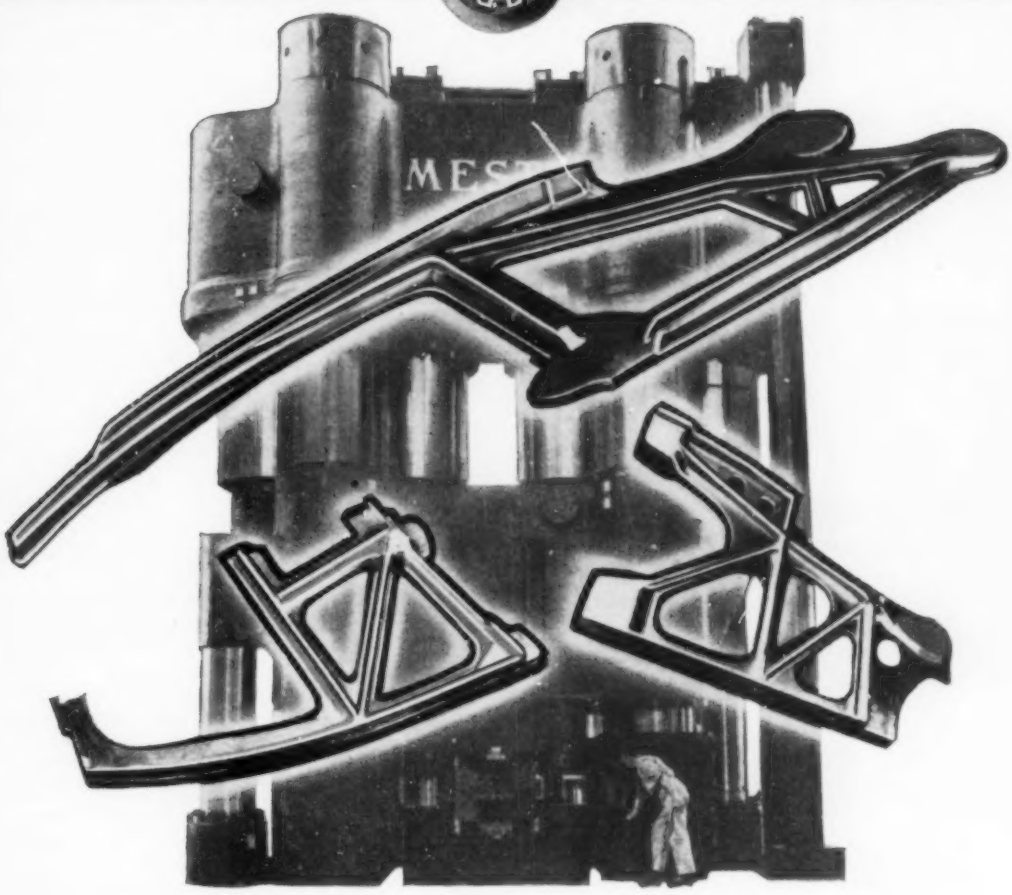
The shape and intricateness of a blank affects the time employed in the building of the die and therefore its cost. Also, stock utilization is usually unsatisfactory in case of complicated blanks. Tolerances must be left as ample as possible, because narrow tolerances require too much extra work which increases necessarily the production costs.

Each time when the design of the pieces allows, there should be a small radius at the corners. This will better the appearance of the part, will make die construction easier, and will increase the strength of the blanking die.

When producing round-edge workpieces cutoff from strips, edges should not be exactly half a circle, but an arc. In the second case, any slight, irregularities in the alignment between strip and cutting off punch are practically invisible.

Relieve Bent Flanges

Second operation forming and bending require special features from the blanks. If only a small projecting portion of a blank must be bent a



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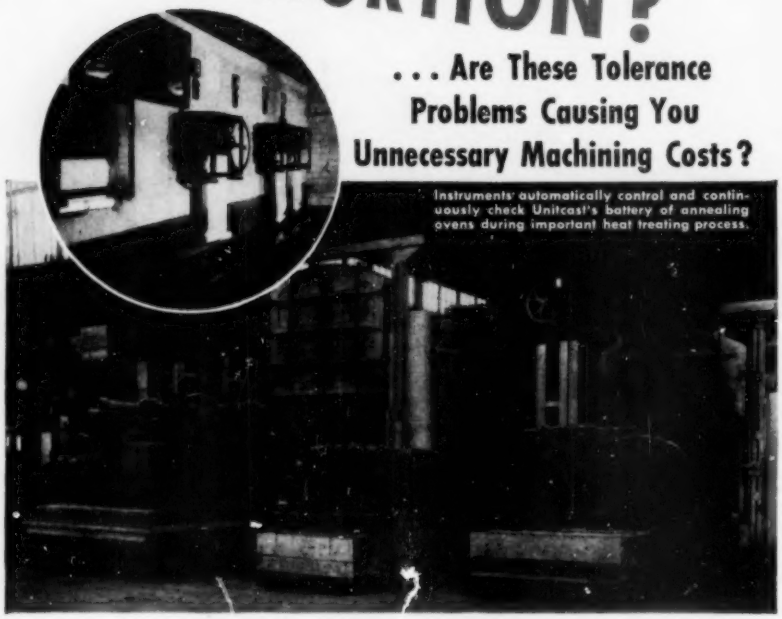

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slight notching in the proper place facilitates the bending operation. The shape of the notching is best trapezoidal. Of course, the best design is when the bending line lies outside of the edge of the larger portion of the blank.

Flanges which are bent only over a portion of the workpiece hole at the point where tearing of the metal is likely to take place. It is also convenient that at the bending line the workpiece contour should meet at right angles.

Holes in bent workpieces should not be too close to the bending line, or they are liable to be distorted by the bending. The hole distance should be at least twice the stock thickness plus the inside radius of the square bend. In case it is necessary to locate a hole closer to the bending line, then a small hole is pierced in the bending line itself. This hole will then be distorted and the chief ones will remain practically unaltered. Another solution consists in piercing the needed holes after the blank has been bent, but this is much more expensive.

Piercing, or blanking, of round holes is always easier than any other shape or form. When a hole must be elongated, it is better made with rounded edges, instead of straight edges.

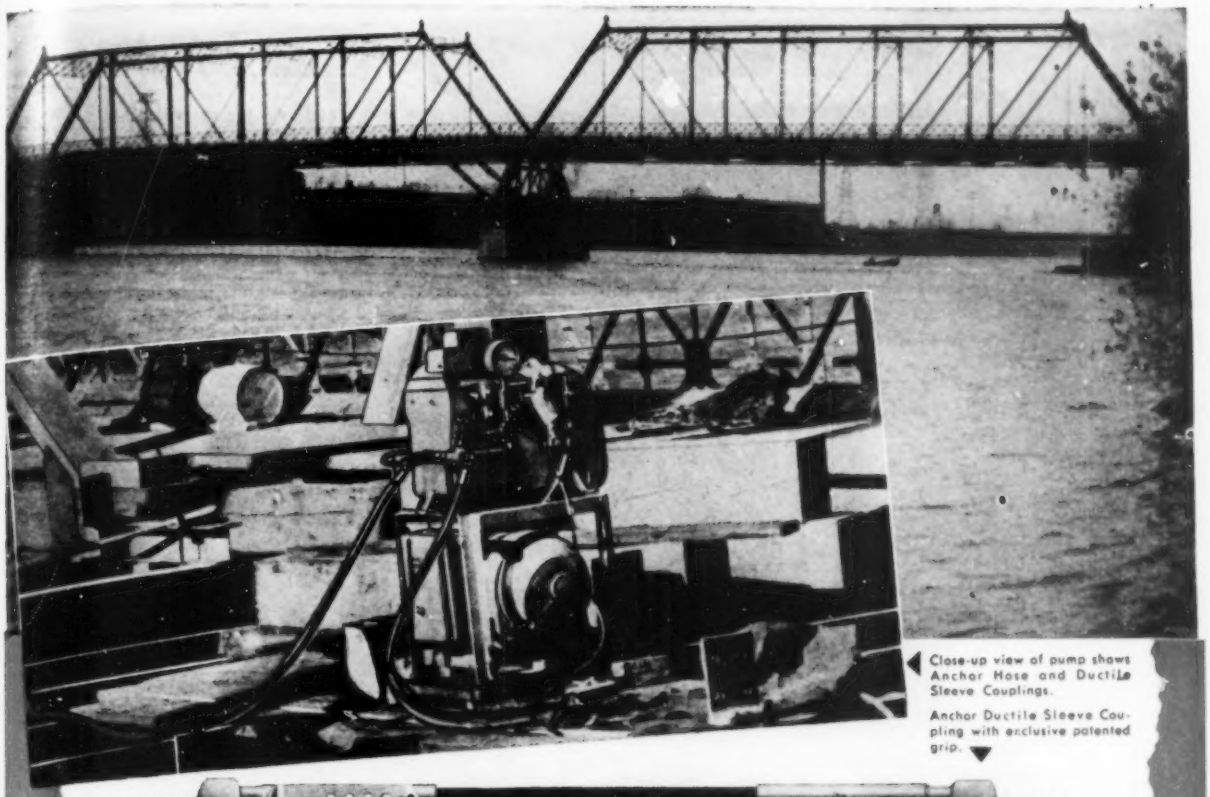
Pierced holes must not be located too near to the blank edges, to avoid distortions on the workpiece periphery. Between the hole edge and blank edge, distance should at least equal stock thickness. When piercing holes in drawn shells the distance from the edge of the hole to the inner wall of the shell should be at least twice the stock thickness, plus radius at bottom of shell.

If a threaded hole is needed in a stamping made from metal sheet, the hole should be extruded. Thus the length of the threaded hole will be doubled.

Lancing or lug forming operations consists of simultaneous shearing and forming of projections or ears. Unless special precautions are taken, the material tears at the points of maximum stress. The solution for this trouble consists in relieving the critical points by notches or by small round holes.

Part Modifications Lower Tool Costs

The bracket in Fig. 3 originally required a progressive type, 2-station, piercing and blanking die. Following a conference between the product engineer and the die-engineer, the part was modified as shown. The new form conserved the location of the three small, round holes, which



Close-up view of pump shows Anchor Hose and Ductile Sleeve Couplings.

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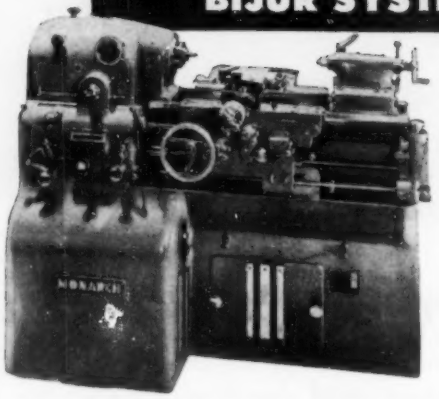
View thru the carriage of a small Monarch Toolmaker's Lathe showing drilled passage from meter-unit to bed way.



In this application, the problem was to maintain a film of oil between the carriage and bed way contact surfaces. It is solved by drilling thru the carriage to an outlet above the "V" way... controlling the oil flow thru a meter-unit at the drilled passage... supplying oil to this point from a built-in lubricator (actuated by a turn of the apron handwheel) which also oils the cross-slide dovetail and the apron bearings. This is another example of Bijur "teamwork for bearing protection." For aid in solving *your* lubrication problems, call in a Bijur engineer.

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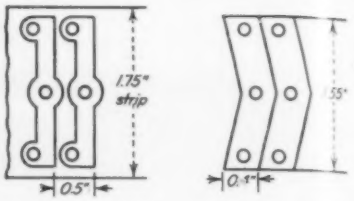

FIG. 3—Original lever design, left, wasted stock. Redesigned lever, right, retains size and locations of holes but is produced with virtually no waste.

FIG. 4—Another case where part redesign is used to lower costs by reducing scrap loss in stamping operation. Former part is shown at left, redesigned part at right.

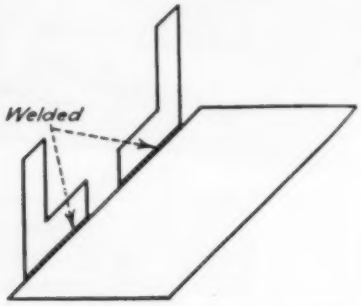

FIG. 5—This part was formerly stamped leaving lugs to be bent up as shown. Now three parts are cut separately and lugs welded on. Cost savings more than pay for welding.

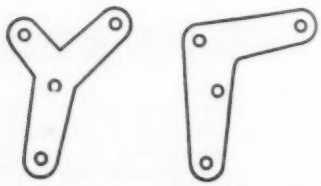

FIG. 6—Design at left is logical in view of location of holes in forging. But design at right retains same hole locations and is stamped with less stock waste.

was the only detail which was important, and permitted making the part with a simple, 2-step progressive-type, piercing and cutoff die. Material saving was almost 30 pct. Also the new die was built at an estimated saving of over 33 pct over the original die.

The part shown at left in Fig. 4 has been slightly changed permitting a much better utilization of the metal strip, as shown at right.

Especially in case of large workpieces, it is often advantageous to

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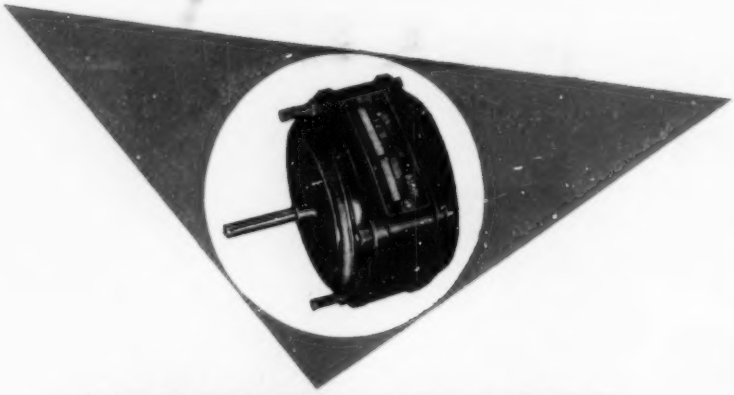

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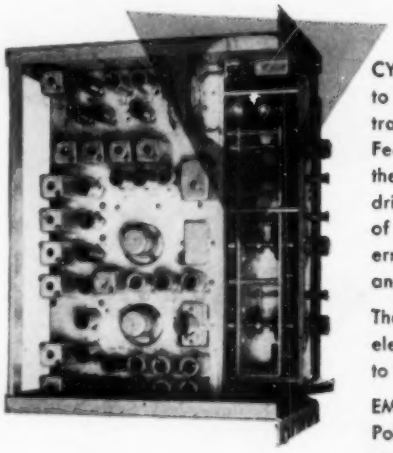

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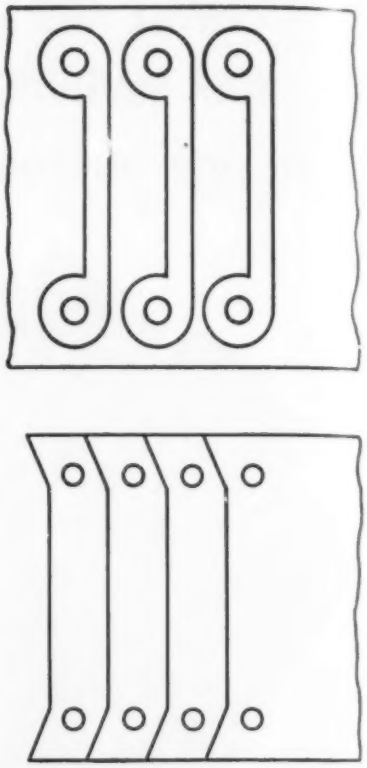

FIG. 7—This part was originally cast. But cast shape would waste stock if retained when converting to stamping as shown at top. Better design is shown at bottom.

make pieces in composite construction Fig. 5, instead of as one piece.

Drawing is not easy. Consequently, when it is necessary to produce deep shells with much more height than diameter, it is probably simpler to make the product in two pieces; a cylinder and a shallow bottom. These can be joined by some riveting, welding, or seaming.

Forgings, Fig. 6 and castings, Fig. 7 can also be redesigned for stamping.

Application of Motors To Household Refrigeration Compressors

Abstracted from "Application of Motors to Household Refrigeration Compressors by L. C. Packer, Member AITEE; *Electrical Engineering*, May 1952

MODERN REFRIGERATION demands a motor-compressor unit of long life, which will operate over long periods with little or no attention with high efficiency. To achieve this end, the designer of the hermetically sealed motors used today must take into consideration a number of factors peculiar to this application.

The trend is for larger refrigerators

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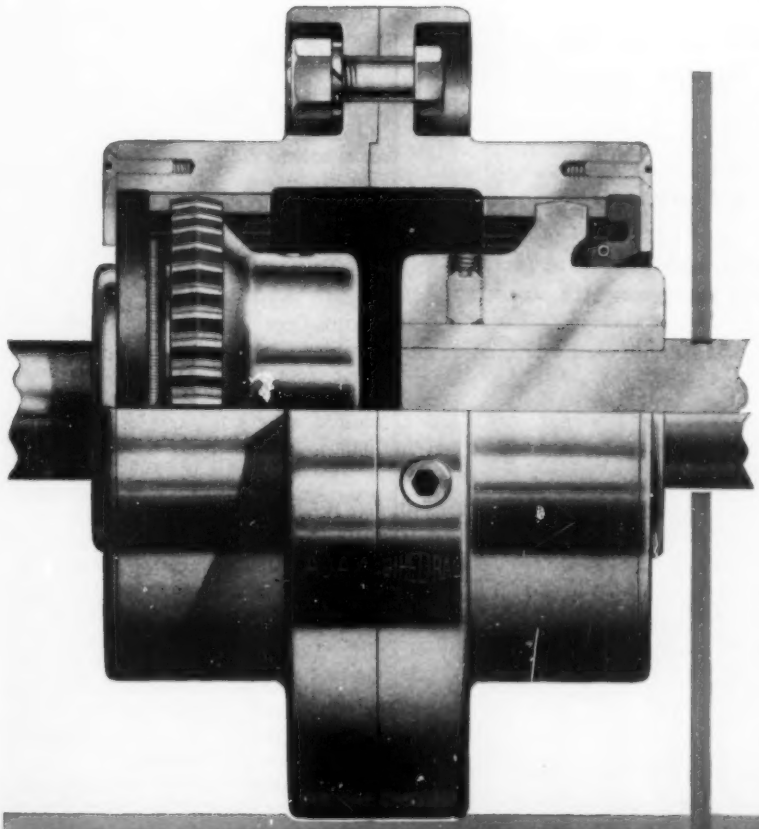

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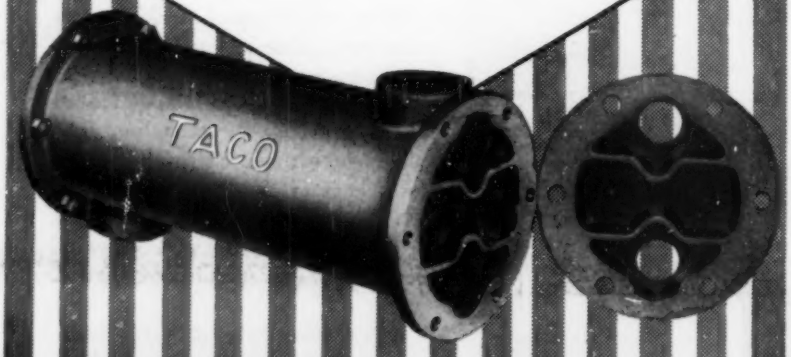

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on the same floor space. This means that the larger food space and frozen-food compartments will require better insulation and more efficient refrigeration units. Less space is also available for the motor and compressor.

It is not within the scope of this article to discuss the complete motor design for household refrigerators, but it is necessary in making a successful motor application for the motor engineers to know (1) the type of motor best suited for the application, (2) the power requirements and performance under all load and voltage conditions, (3) how the motor is to be started, (4) the maximum permissible motor temperatures, (5) that the motor is properly protected from overheating, (6) the chemical reactions that take place with various materials in the complete sealed unit, (7) the mechanical design of the motor and the materials necessary to satisfy the application, (8) the importance of mechanical, as well as chemical, cleanliness, (9) the compressor design in so far as it affects the assembly of the motor, and (10) the possible causes of motor failures in service which will not only be of considerable value to the motor designer, but also to the designers of the compressor and the other electric equipment.

Neither d-c nor repulsion-type motors are applicable to hermetically sealed compressors because of the commutator and sparking at the brushes. A-c motors of the squirrel-cage rotor type can be designed and built to handle almost any range required, except for exceptionally wide ranges of voltage.

The motors for household refrigerators are usually of the single-phase 4-pole 60-cycle 1,725-rpm type with split-phase starting. Ratings vary from one-tenth to one-quarter horsepower. However, the horsepower rating does not mean much, as the motor is designed for specific compressor applications. There may be instances where it is desirable to use a capacitor start motor to obtain more starting torque, but capacitor start motors seldom are used in household service.

The motor that drives the compressor must be adequate to drive the compressor to obtain the required amount of refrigeration. It must have sufficient starting and accelerating torque to start and accelerate the load, and have sufficient breakdown torque to handle the maximum load at the lowest practical voltage at the terminals. The motor also must operate at a satisfactory temperature under operating conditions for the required life and at an efficiency to give low operating cost consistent with the initial invest-

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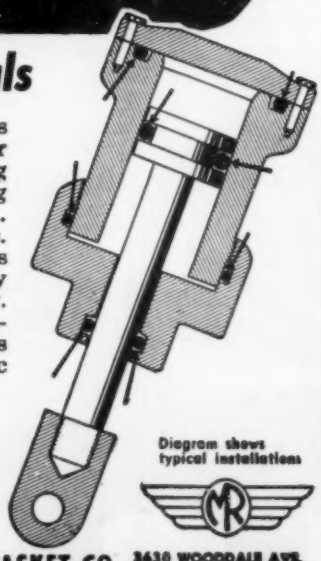

Diagram shows typical installations

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ment under the practical minimum and maximum voltage conditions.

Details on motor starting, overloading and chemical reactions are covered fully in this article. A single-phase motor will not start without some auxiliary starting means. From a practical standpoint, it is necessary to wind into the stator core a starting winding displaced 90 electrical degrees with respect to the main or running winding. The combination of both windings produces sufficient torque to start and bring the load up to a predetermined speed. The starting is the cut out and the main winding takes the load on up to speed. The starting winding is usually cut out at a speed just above the breakdown-torque point of the main winding. If the load should become excessive, arrangements can be made to pick up the starting winding at a point below the breakdown torque of the main winding and take the load up to speed again because the torque of the combined main and starting winding is greater than that of the main winding only. Operation of this type of motor for short periods under heavy pulldown conditions at acceptable minimum voltages is permissible. However, too frequent operation under these conditions is detrimental to the life of the motor, contacts of the relay, and the protective device.

It is not permissible to have any transfer switching means such as centrifugal switches inside of the hermetic unit because of the inherent sparking; therefore, relays of various types must be mounted outside of the compressor.

Mechanical Design of Motor Parts

The motor industry through National Electrical Manufacturers Association (NEMA) has standardized on the stator outside diameter with tolerances, stator widths over the winding, and rotor bore with tolerances which permits the compressor manufacturer to establish standard dimensions and tolerance for the proper shaft fits in the rotor and the fit between the stator core and housings.

The motor laminations are made from the lowest core loss, highest permeability, and greatest thickness electrical sheet steel consistent with the high performance necessary, low cost, and good punchability of the steel. The refrigerator manufacturer is interested in both high efficiency and low costs. In most cases, the stator laminations are annealed to improve performance.

There must be sufficient rigidity in the stator construction to withstand ordinary handling without disturbing

Complete service on T and W deep drawn stampings

This fully equipped Die Room, plus modern production equipment and thorough engineering, is available to T & W customers.

For those manufacturers having their own press equipment Transue will gladly quote on die requirements.

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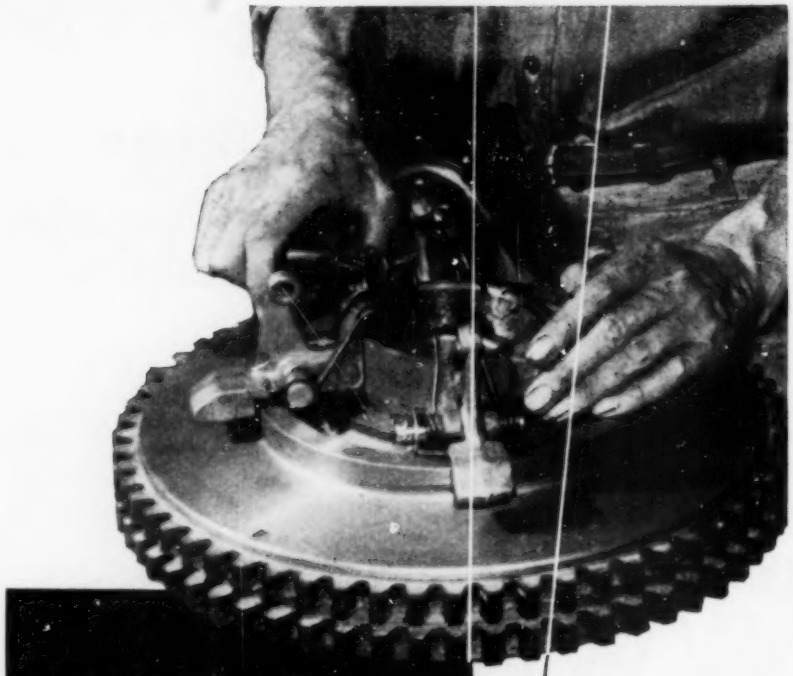
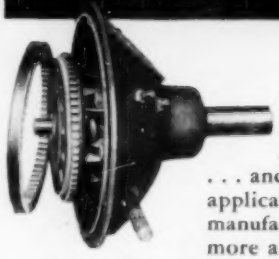


Cut Downtime . . . Step up Worktime



More Friction Power Take-Offs . . . in more sizes . . . and in more fields of application than any other manufacturer. That's why more and more manufacturers and users of powered equipment are standardizing on Twin Disc Power Take-Offs.

Standardization on Twin Disc drives is a profit-making practice because it assures you (1) long work life; (2) ready availability of parts and services; (3) interchangeability of parts; (4) advantage of specialized "know how" by repair departments; (5) minimum parts inventory requirements.

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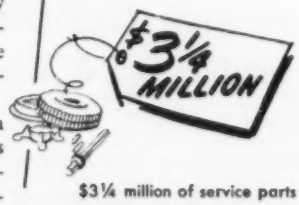
8 Factory Branches and 60 Parts Stations strategically located.



$3¼ million of service parts and complete replacement units carried in inventory.

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the close machining tolerances, thus facilitating assembly by the compressor manufacturer and promoting quality apparatus. Either welded or riveted stator cores or a frame wrapped around the stator core may be used, depending upon the features desired in the individual designs.

To date, the only practical insulation for the motor has been of the organic or AIEE Class A type. Paper is used for slot cells, barriers, slot wedges, separators, and connection and crossover wire sinulators.

Cotton is used for sleeving over lead wires, and for binding the winding. The stator wire is usually covered with a polyvinyl acetal or other types of enamel. Sometimes the enamel has a cotton covering the starting winding. Enamel wire in the main winding has resulted in more efficient designs compared with previous designs using double cotton covered wire. The stator windings may be put in by hand or, in many cases, the main winding at least is wound by machine which results in greater accuracy in the number of turns and lower cost.

As the windings in the stators for household refrigerator compressors are not impregnated with varnish, they will loosen at the end winding and also shift slightly in the slots. They are tied, but it is impossible with the type of insulation used to tie down the wires so that there is no relative motion in service after the paper and cotton are saturated with oil. Tightly wedging the wires in the slots minimizes any movement that no abrasion will result and cause short circuits or grounds. The motor manufacturer should maintain certain outline dimensions of the stator windings as consistent as possible with the nature of the winding.

The rotor is manufactured of the same grade of steel as the stator core and with either copper or die-cast aluminum cage. Aluminum free of magnesium and impurities is suitable for use in Freon-12 or sulphur dioxide, but not in methyl-chloride systems. The laminations are annealed before assembling into cores for die-cast rotors, and in many cases for copper-cage rotors. This eliminates the stray load losses, which cause dips in the speed-torque curve, and which reduce the pull-up and breakdown torques and efficiency. After the rotor is cast and the rotor surface and bore are finish machined, the complete rotor is then given a special heat treatment to reduce the stray load losses caused by die casting and machining operations. Many copper-cage rotors also get this treatment.

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Your products gain prestige when they are powered with Packard fractional horsepower motors. The Packard motor's name is so widely known—so greatly respected—that customers value your product more when they see it is Packard powered.

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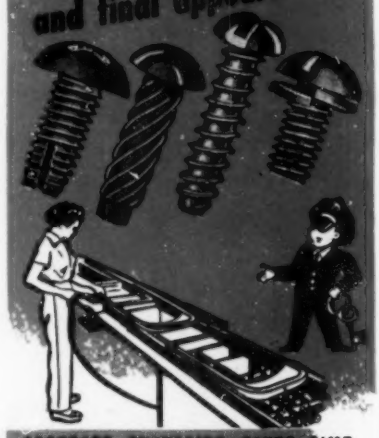
save assembly time
improve product strength
and final appearance



ACCURATE THREADING SAVES TIME

Pheoll Screws, Bolts, and Nuts are easier to start, easier to drive and easier to tighten—because they're accurately machined and threaded. These features cut your assembly time and cost.

COLD ROLLED THREADING ADDS STRENGTH

The grain structure and flow of metal obtained through cold heading and roll threading increases the structural strength of Pheoll Fasteners. Cold working improves thread bearing surfaces, providing greater area of contact for firmer grip. Greater strength reduces possibility of shearing, and time lost in subsequent removal and re-tapping.

OUR INSPECTION IMPROVES YOUR PRODUCT APPEARANCE

Step by step Pheoll inspection, through every process of production, assures uniform head size and shape; cleanly milled and recessed heads, neat chamfering and countersinking. All these factors contribute to the quality and finish which add materially to your product's final appearance. *Write* for Pheoll's product literature and price list.

THESE PHEOLL PRODUCTS INCREASE YOUR PRODUCTION RATE. Thumb Screws Machine Screws† • Wood Screws† • Sheet Metal Screws† • Stove Bolts† • Rolled Threaded Wires and Studs • Special Rivets and Pins • Brass Washers

†Furnished in slotted and Phillips Recessed Head Types

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SCREWS • BOLTS • NUTS

necessary in manufacturing hermetically sealed units is cleanliness. The motor and compressor manufacturers have separate, as well as joint, responsibilities in maintaining cleanliness of the motor and compressor parts and the complete assembled unit.

Compressor Construction

Common bearings are used for both the pump and motor and they are designed to provide adequate capacity for the combined load of the pump and motor. The crank-shaft serves the pump and carries the rotor of the motor. An adequate lubrication system must be supplied and sufficient oil to last the life of the unit.

The stator is assembled into the housing with a press fit. This latter fit plays an important part in the transfer of the hea through the housings. The fit must be tight enough to hold the stator in place in the housing, even in vertical units, yet it must not be so tight it will distort the stator. The unbalanced magnetic pull and noise from the motor increases rapidly with an uneveness of the air gap between the motor stator bore and rotor. This pull increases the pressure on the bearings and may break down the oil film. It also increases the stresses in the shaft. Therefore, the construction of the housing must be such as to permit accurate machining and assembly. An excess of oil in the air gap of the motor causes a drag on the rotor and requires more power input to maintain a given load.

Hot Pressing Powdered Metals

Abstracted from Hot Molding Increases Scope of Powder Metallurgy by Jerome F. Kuzmick, President, American Machinist, July 7, 1952

SIMULTANEOUS APPLICATION OF PRESSURE and heat to metal powders—hot pressing—has for a number of years attracted the attention of powder metallurgists. Early experiments demonstrated that

1. Pressure required for hot molding metal powders is considerably lower than is normally used for cold pressing.

2. It is possible to hot press metal powders to solid density in one operation without sintering.

3. Properties of hot-pressed alloys are similar to those of hot-forged, or cold-worked and annealed materials.

On the other hand, early experiments also pointed out some of the difficulties, such as:

1. Lack of suitable die materials to

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It's a natural . . . and important question to ask . . . a hard question to answer without reference to past performance under the toughest *in-combat tests*. We reflect the judgment of many leaders in product engineering when we remind you of the way our product continues to meet the highest in quality standards:

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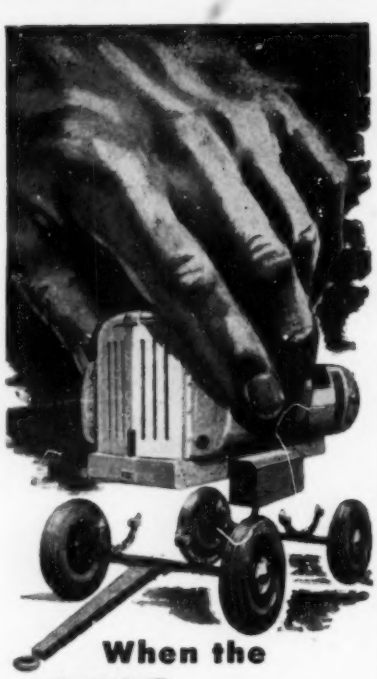

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CARAVAN axles can be furnished in two-wheel, single-axle assemblies and as four-wheel running gear equipped with automotive type steering mechanisms. Straight and drop axle type construction is available.

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withstand elevated temperatures, which generally are about the same as the sintering temperature.

2. Rapid heating of the metal powder and need for protection against oxidation.

3. Prevention of welding of the compact to the die as a result of hot pressing.

4. A rapid enough cycle to make it practical.

No process is known to have been put into operation for rapidly producing hot-pressed metal-powder mechanical parts on a commercial scale; although hot-pressing has been successfully applied to a number of applications involving costly materials, where this process is the only one which gives the desired results, and cost is secondary. Generally, two methods are applied:

Type 1. Hot Forging—in which normally cold pressed and sintered parts are removed hot from the sintering furnace and subjected to a forging operation, usually in water-cooled steel dies.

Type 2. Hot Molding—where pressing and sintering are simultaneously performed in one operation. The charge in the die may be the metal powder itself, or it may be a preform which has previously been molded by the usual cold-pressing method.

Hot Molding Applied

Large tungsten-carbide sections have been hot pressed for some time. In this process, molds are machined from graphite bar stock. In most cases, molds are the so-called "Closing type;" that is, they are so dimensioned that the proper-size piece is produced when the plungers have compressed the carbide mixture and the outer ends of the plungers are flush with the upper and lower surfaces of the die barrel.

From the known density of the end product, the weight of the desired carbide mixture is calculated and the required volume poured into the die cavity. The plungers are lightly pressed into the cavity and the mold positioned in the press. The piece is hot pressed at relatively low pressure, on the order of 1000 psi. Final temperature is similar to the temperature used for sintering cold pressed carbide, usually about 2,450 to 2,650F depending upon cobalt content. Underpressing must be avoided because porosity will result in the finished carbide. On the other hand, overpressing will cause excessive squeezing out of cobalt binder, causing improper binder content and local segregation of cobalt, which again results in porosity or soft spots. For this reason, even

"Joe, how can we save money on these small parts?"
"Have Torrington make them, Tom! They have the know-how and the equipment to produce precision metal parts at a fraction of what we'd pay anywhere else."

When it comes to holding the line on costs—and holding strict tolerances at the same time—it takes experience and facilities. For over 86 years, Torrington has been making precision metal parts. Production facilities include batteries of automatic and semi-automatic machines—many of them Torrington-designed—and one of the finest heat-treating departments in the world. In addition, we have at our disposal the combined experience and facilities of all 11 plants of The Torrington Company.

If you need precision metal parts, ask us for a quotation. Just send us a sample or blueprint and tell us how many you need.

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Bearing performance with Rolled Bushing Economy when you use our Bimetal Bushings

Research, engineering and quality control departments to assist you. Specialized, large-run production facilities. Capacity now available!

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Bronze, babbitt or copper-lead lining.

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Lining materials bonded to steel backs.

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Rolled from bimetal continuous strip.

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½ to 40,000 HP
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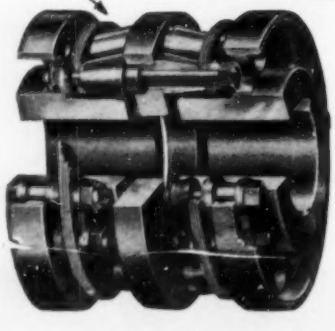

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NO MAINTENANCE PROBLEMS.

ALL PARTS ARE SOLIDLY BOLTED TOGETHER.

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WARREN, PENNSYLVANIA

with closing type molds, compression of the carbide charge is carefully measured with dial indicators.

Unfortunately, in most cases, it is impossible to salvage the graphite mold, so it is used only once. However, there are many cases where this procedure is economically practical. On plain round cylinders and bushings, standard round graphite bar stock can be purchased in a number of sizes, so often simple cutting-off and drilling operations will produce the desired mold.

On small pieces, it is possible to use multicavity molds in which several pieces are made simultaneously. For shaped pieces, it is often easier to machine a graphite mold than it is to machine presintered cold pressed carbide, which is very fragile and must be handled with extreme care. One advantage of hot-pressed carbide is the absence of shrinkage from sintering. It is well-known that cold-pressed carbide may shrink as much as 18% linearly or 50% by volume during sintering. Thus it is difficult to avoid distortion on odd-shaped pieces or long thin-walled sections which may vary in density as cold pressed. On the other hand, the hot-pressed carbide fills the mold cavity as it compresses, and the dimensions are those of the mold cavity.

Repressing Tungsten-Carbide Dies

In these days of metal shortages, anything that can be done to conserve such strategic materials as tungsten and diamond powder is, of course, highly desirable. Hot molding is applied at Welded Carbide Tool Co. to save tungsten-carbide drawing dies.

When dies have been worn beyond bore tolerance, the ID is usually ground to the next larger size. This may not be too arduous on very-small-bore dies. However, as size increases, the difficulty of this practice also increases because the next-larger-size bore may require removal of a considerable amount of carbide, and consequent wear of diamond wheels. The bore cannot be increased very much before the die wall becomes too thin, and the sizable piece of tungsten carbide must be discarded.

Thousands of drawing dies have been salvaged in this shop by hot pressing. The die is placed in a graphite mold with a core of the desired diameter, minus several thousandths of an inch grinding allowance. The die is hot pressed in the mold, and the carbide compressed slightly as it becomes plastic, thereby filling in the bore and losing a little in height. As a result, carbide is taken out of the height, which is critical. The graphite molds

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Important not only in precision ball bearings, but also in the lot of other applications where Strom metal balls have been doing the job better. Strom has been in on a great many ball-application problems, and knows how important these two factors are for the best results.

Strom has been making precision metal balls for over 25 years for all industry and can be a big help to you in selecting the right ball for any of your requirements. In size and spherical accuracy, perfection of surface, uniformity, and dependable physical quality, there's not a better ball made.

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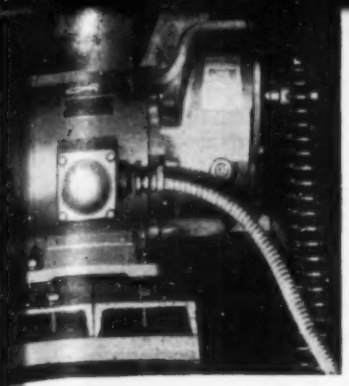
Largest Independent and Exclusive Metal Ball Manufacturer



Single Reduction Gearmotor

Triple Reduction Gearmotor

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Double Reduction Type OGX 2-HP Gearmotor

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These Gearmotors save space, eliminate operating headaches, and greatly reduce maintenance costs. They are streamlined power units combining compactness, efficiency, and long life. Available in ratings of 1 to 150 HP with 40 HP and smaller units in all output speeds and AGMA classes in stock for immediate shipment.

Better still, there's a Foote Bros.-Louis Allis Gearmotor *exactly suited* to your particular job. Check these features for job fit and dependability:

✓ **Complete range of output speeds** 780 to 7.5 RPM. Rated for AGMA Class I, II, or III service conditions.

✓ **All types of motor enclosures** — Open, Drip-Proof; Splash-Proof; Enclosed, Non-Ventilated; Enclosed, Fan-Cooled; Explosion-Proof; also A. C. Wound Rotor, and Direct Current Motors.

✓ **Extra capacity ball and tapered roller bearings** throughout for trouble-free service under severest conditions.

✓ **Maximum wear resistance — high load carrying capacity.** Precision, file-hard gear tooth surfaces with tough, resilient cores.

✓ **Quiet, vibrationless operation,** even under continuous reversing service. Tang-driven motor-shaft pinion provides quiet, vibrationless operation.

You'll like these features, and the many, many more that make Foote Bros.-Louis Allis Gearmotors your best buy in smooth, dependable, low-maintenance power transmission. Get further information about these money-saving units *exactly suited* for *your* job. Write today for Bulletin 1000 or contact the Louis Allis District Office nearest you.

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Standard or special — we build it. Whatever electrical or mechanical modifications or features you need, there is a Louis Allis motor that will do your toughest jobs better.

"SPECIAL"
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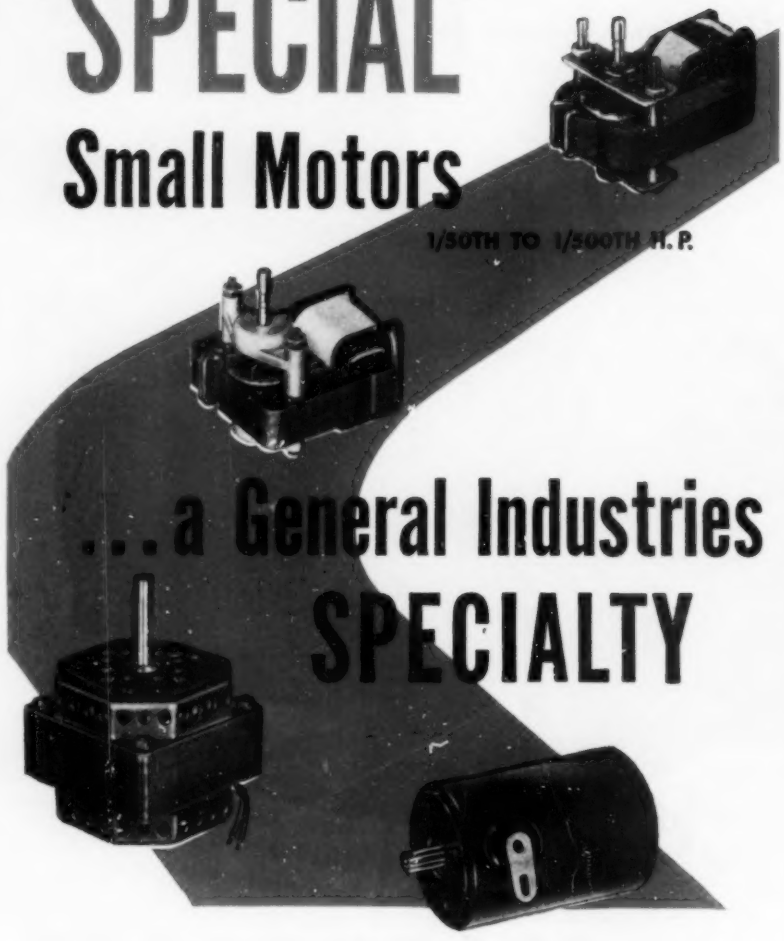

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2. A large engineering and research staff; extensive experimental facilities, including up-to-date model shop and completely-equipped testing laboratory.

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Write, wire or phone for information pertaining to your specific small motor problem.

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can be used several times, and the surfaces of the carbide die retains a fairly good finish. As a result, only a few thousands of an inch need be ground from the bore surface to produce a high degree of accuracy and finish on the die.

Heavy Metal Products Made

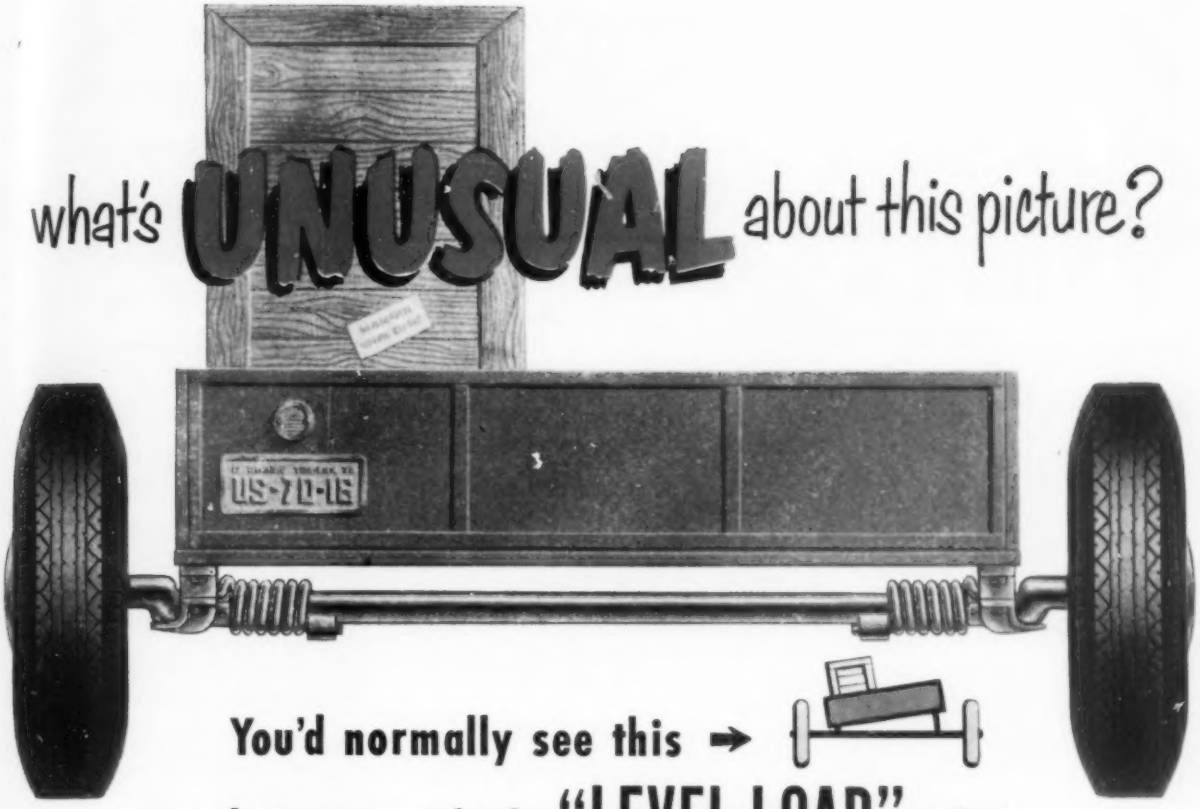
A recent development in hot pressing of powdered metals is the production of parts from heavy metals. For more than a decade, such parts have been made by the cold-press-sinter process. They consist of about 90% tungsten and 10% of a nickel-copper binder. Their theoretical density ranges from 16.5 to 17.2 for the usual percentages of binder employed.

Difficulties involved in the production of cold-pressed sintered heavy alloys are similar to those in sintered tungsten carbide. If it is desired to obtain densities close to theoretical, great care must be exercised in controlling particle size, purity of powders, sintering temperature, etc. During the sintering of cold-pressed pieces, shrinkage as high as 20% linearly may take place. This makes it difficult to control dimensions and to prevent distortion, particularly on large sections. For such objects as tall bushings, it is impossible to eliminate the "hour-glass" shape because of differences in density along the length prior to sintering.

In developing the hot-press method for producing high-density materials, the usual graphite molds were used. However, one of the first problems encountered was carburizing of the tungsten by the mold. A coating was developed which, when painted or sprayed on the mold, not only prevents this carburizing tendency, but also protects the mold itself. Thus, a number of pressings can be made from one mold.

With this method, it is relatively easy to achieve full density, and parts have been produced to densities ranging from 16.5 to 17.1, depending upon the particular composition. There is no problem of distortion, as the metal under heat and pressure completely fills the mold. The structure of the hot-pressed heavy alloy is much finer in crystal size than that of its cold pressed-sintered counterpart. This is because the hot press cycle is relatively fast, whereas sintering to high density requires sufficient time for considerable growth in the crystal size of the tungsten. Machinability of the hot-pressed alloy is considerably better than that of the sintered material, and it is believed that this is a result of the difference in crystal structure.

what's UNUSUAL about this picture?



You'd normally see this →

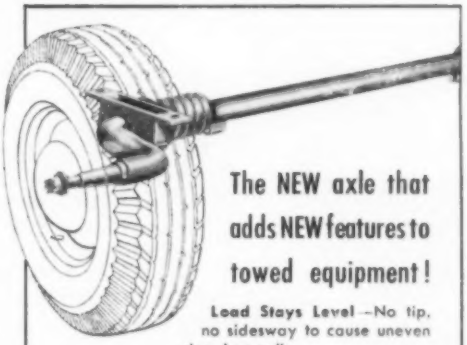
but not with the "LEVEL-LOAD" axle!

An axle that evenly distributes load weight on both springs—*regardless of load placement*—can't help but offer makers of towed equipment more freedom of design and layout. And it's here now . . . the ASF-Linco "Level-Load" axle!

Each end of this unique axle has a spring-controlled floating spindle arm, forged as a solid, integral unit with the steel shaft. Road shock on one wheel, or an off-center weight, is absorbed by both springs—*equally and simultaneously*. The inevitable result is a load that stays level without tilting or sidesway; a load that tracks better and pulls evenly on the drawbar.

And, as the spindle arm moves downward with increased loads, spring leverage *decreases*. Spring tension and load weight are automatically maintained in easy-riding proportion to each other!

If you design any kind of towed equipment . . . welding machines, sprayers, utility trailers, mixers, etc. . . . get all the facts on towing at its level best! Write American Steel Foundries, 410 North Michigan Avenue, Chicago 11, Illinois.



The NEW axle that adds NEW features to towed equipment!

Load Stays Level—No tip, no sidesway to cause uneven drawbar pull.

Easier Riding—With spring tension that automatically adjusts to load weight.

Bigger Capacity—Than any other axle of similar rating.

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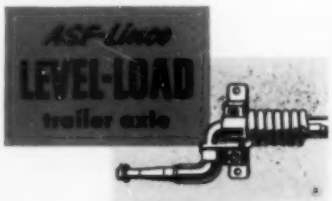
And, easy to install on your production lines! It's a completely assembled unit. Just 4 bolts (single) or 8 bolts (tandem). No equalizing bars needed in tandem mounting.



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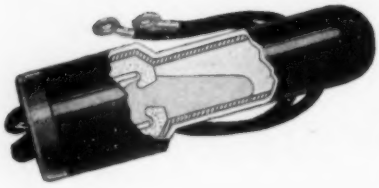

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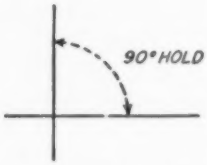
OUR READERS SAY

Trends in Tolerance Specifications

To the Editor:

Especially on the West Coast, product, tool, and machine design drawings are becoming more specific in their notations of tolerances for concentricity, parallelism, perpendicularity, and in many cases "matching." Notes and symbols are being standardized, and are proving their worth by eliminating the use of "judgement" by the machinist and inspector, and the arguing and bickering between these individuals which invariably result when drawings leave specifications up to the shop.

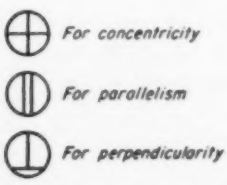
The prevalent use of notes such as, "These surfaces must be parallel," "These surfaces must be perpendicular," or



certainly isn't in keeping with the principle of building to specifications so necessary in the operation of a modern large plant. These notes are on the way out and should be assigned to "limbo" with "tight snug fit," "loose snug fit" and such dimensional specifications to which the old timer built his contraptions.

One large firm has standardized the use of the following symbols in the picture with the tolerances specified at the bottom of the drawing along with the tolerance notes for the decimal, fractional, and angular dimensions.

These are:



An example using these symbols is shown in Fig. 1.

This system commends itself as being a saver in drawing time since the tolerance block can be rubber stamped at the bottom of the drawing, or can be

CLUE TO A SOLUTION FOR YOU?
GAST Oil-less AIR PUMP does double duty on HOMOCARB FURNACE

PROBLEM: Get a compact pump that provides both vacuum and pressure in a gas-air system required for operation of Leeds & Northrup Microcarb Atmosphere Control applied to the Homocarb Furnace equipment.

SOLUTION: One Gast Integral Oil-less Air Pump does double duty. It provides low vacuum to draw a continuous 2 cu. ft. per hr. sample of furnace gas over the atmosphere detector. At the same time the pump maintains a mixture of furnace atmosphere and air at 5 to 10 pounds pressure in the system on the discharge side of pump.

RESULT: Positive displacement pump provides absolutely oil-free air, and eliminates worries about lubrication. Rotary design runs quiet and cool.

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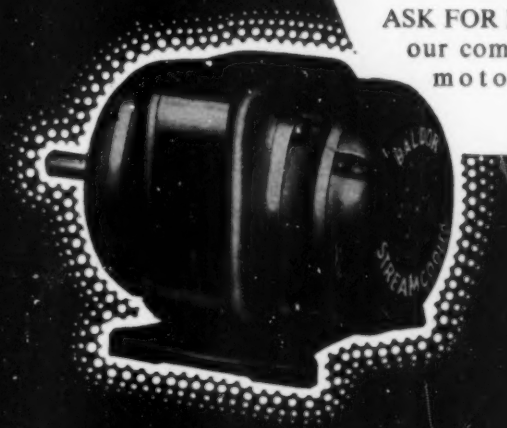

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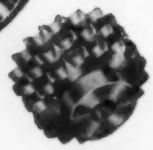

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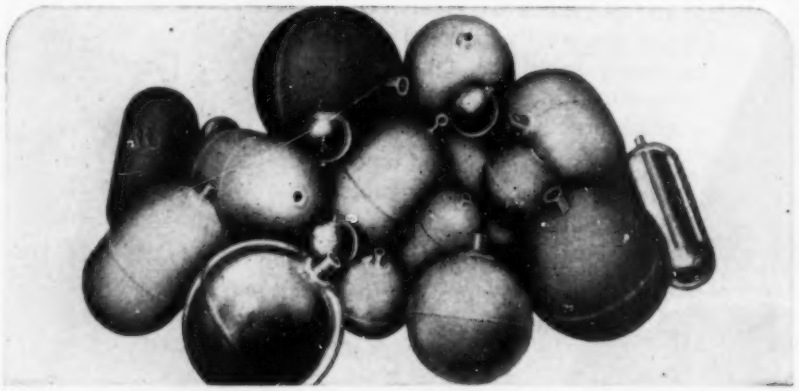

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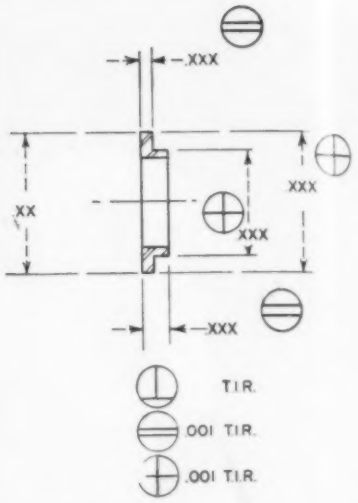
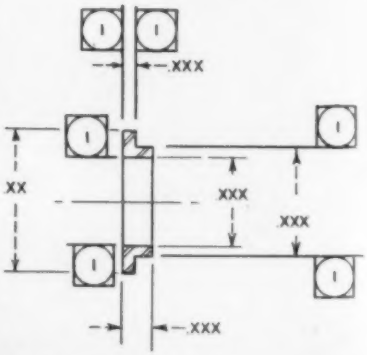


printed in with the dimensional tolerance notes.

Another large company uses one symbol: [1] with a standardized note on the drawing that reads: Surfaces marked thus [1] to be parallel within 0.0005 in 10 inches. Or the note may read: Surfaces marked thus to be in plane within 0.0005 in 10 inches. Or again, it may read: Surfaces marked thus [1] to be normal with 0.0005 in 10 inches. The tolerance is variable to suit the design, but the 10 in. extension is standardized for small work. The "in plane" specification refers to the control of twist.

Some firms streamline all the above with one general note reading: [1]. These surfaces concentric, parallel, square and true to each other, as applicable, within 0.0005 T.I.R. The above drawing in this case would look as shown in Fig. 2. This type of specification leaves much to be desired but is still better than nothing.

The general practice for matching is to use tolerances that call out the maximum allowable mismatch when



[1] *These surfaces concentric, parallel, square and true to each other, as applicable, within .0001 T.I.R.*

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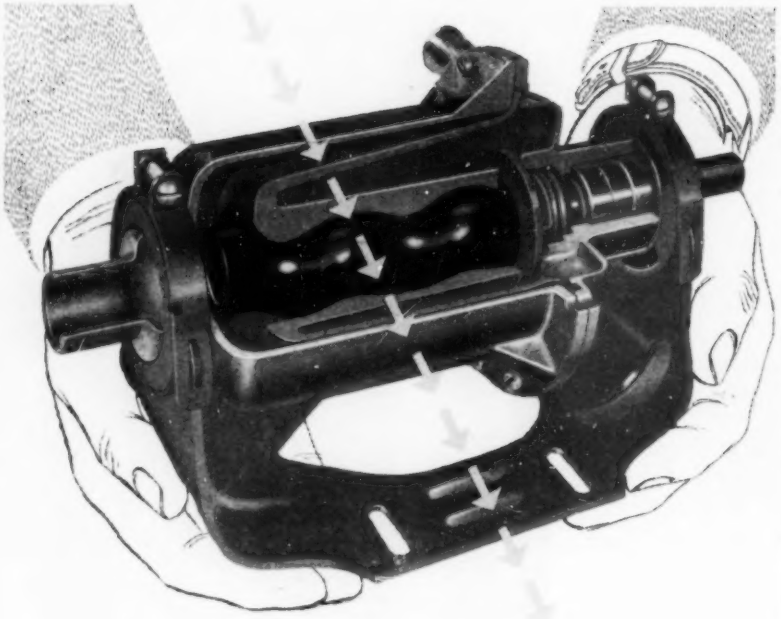

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This rotor on the pump of an automatic washing machine is the first such application of a plastic part. Mass production of the piece (tolerance of ± .003") gives our customer an appreciable savings in cost over the part previously used, an 80% reduction in weight, plus a wear-defying impact strength that results in maximum pump efficiency.

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matching one tool to another or a master to a tool. Hole pattern matches must specify maximum allowable undersize pins to establish respective match. A sample note specifying a match tolerance will be similar to the following which refers to matching the hole pattern to a master: "Bushing location to match T68457 Master using a maximum of 0.001 undersize pins."

—AARON H. SHUM

Magnetized Steel Stampings

To the Editor:

We are manufacturers of small stamped sheet metal parts. In this process we find that we get quite a bit of magnetism.

Can you suggest a method for overcoming this, or perhaps recommend some firm that could be of assistance to us. —OLOF HAGGBLAD, ENGINEER
Ernst Slide Fastener, Inc.

Ed—The magnetism may come from either of two sources. It may be induced as a result of orientation of the molecules during stamping, or it may be the result of static electricity incurred during stamping. If it is straight magnetism, it can be cured by changing the type of steel you are using, or if this is not possible, by using a demagnetizing coil. A representative from your steel supplier can probably advise you as to the choice of material.

If it is necessary for you to use a de-magnetizing coil, you might contact the Magnaflux Corp., 5900 Northwest Highway, Chicago, Illinois; or O. S. Walker Co., 1000 Rockdale St., Worcester 6, Mass.; or any of the companies that make magnetic chuck holders.

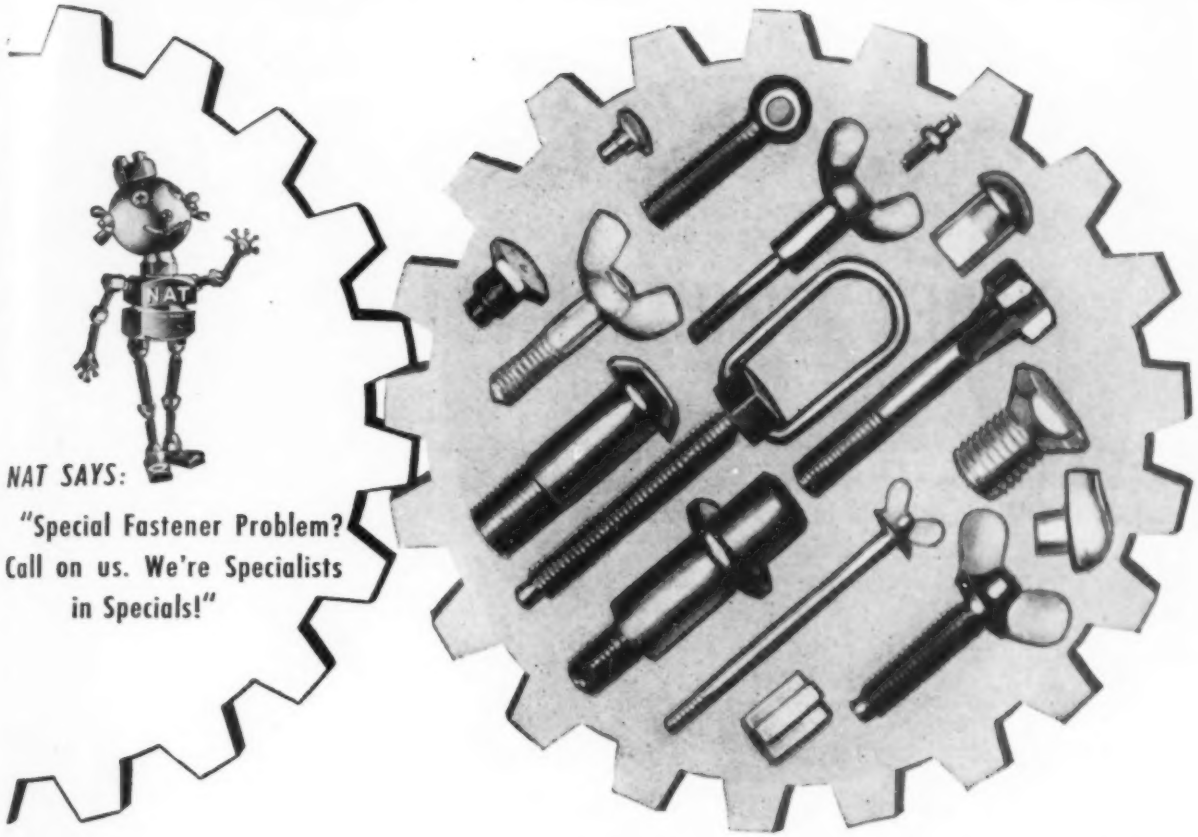
If the magnetism is being caused by static electricity, it can be eliminated by using a strip of radioactive polonium near the exit where the parts leave the punch machine.

I hope that this information will be of assistance to you.

Government Scholarships

To the Editor:

Your editorial "Colleges and Political Domination" in the March 1952 issue of PRODUCT ENGINEERING was tops. Without wasting a word, I believe you put your finger on the two major weaknesses of government scholarships for a college education: inefficiency in administration, and political patronage. You also offered what I believe to be an excellent alter-



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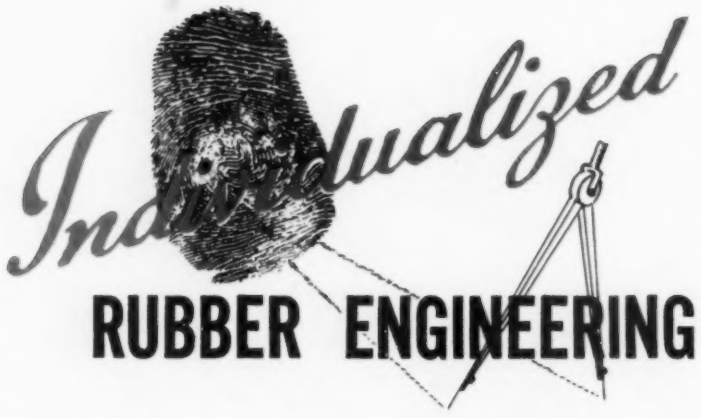
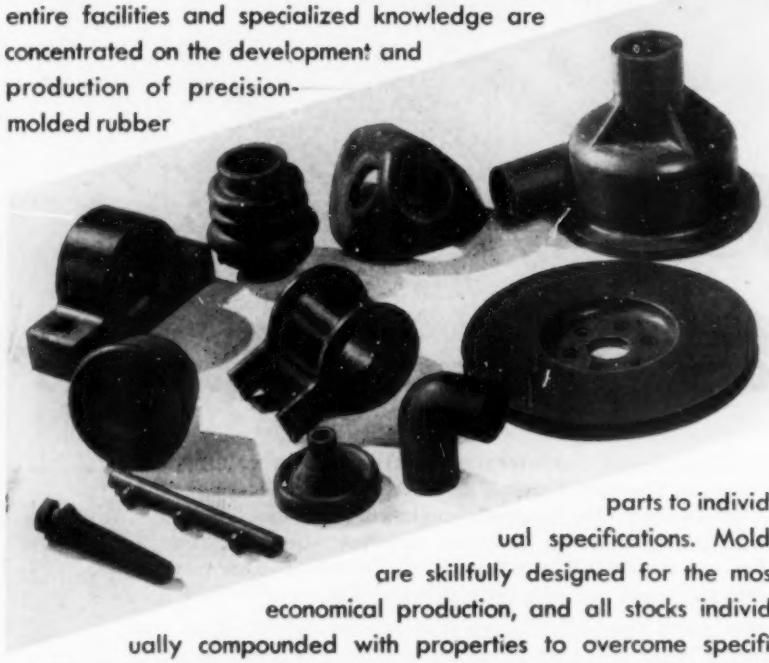


Here at ACUSHNET we are completely staffed to give individual engineering service on each individual order, through each stage of production. As we do not make or stock standard items, our entire facilities and specialized knowledge are concentrated on the development and production of precision-molded rubber



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native; the making of college expenditures tax exempt.

It seems a crying shame that a government should be allowed to tax the public to the tune of $30,000,000 in order to return $25,000,000 or less in the form of benefits. The lower the administrative level at which a job can be done the more efficiently it can be done. One would have to go a long way to get a spending job done more efficiently than the average citizen who had to earn the money being spent. And your proposal of tax exemption would reduce it to just that.

Maybe the coming presidential election will begin a reversal of the tendency to rush headlong into socialistic and wild spending. Evidently we both sincerely hope so. —DAVID C. KAY

Likes May 1952 Feature Article

To the Editor:

It was a pleasure to learn that it will be possible for us to have a reprint of the very excellent article appearing in the May 1952 issue of PRODUCT ENGINEERING. This article on "Engineering Your Company's Future" is one of the most outstanding articles I have seen for some time. We will make very good use of this reprint.

—MAURICE NELLES, DIRECTOR
Borg-Warner Research Lab.

Burned Out

To the Editor:

We are turning to you for assistance. We were recently burned out, and lost all our files. We now have very little reference, data, and are calling on you to help us.

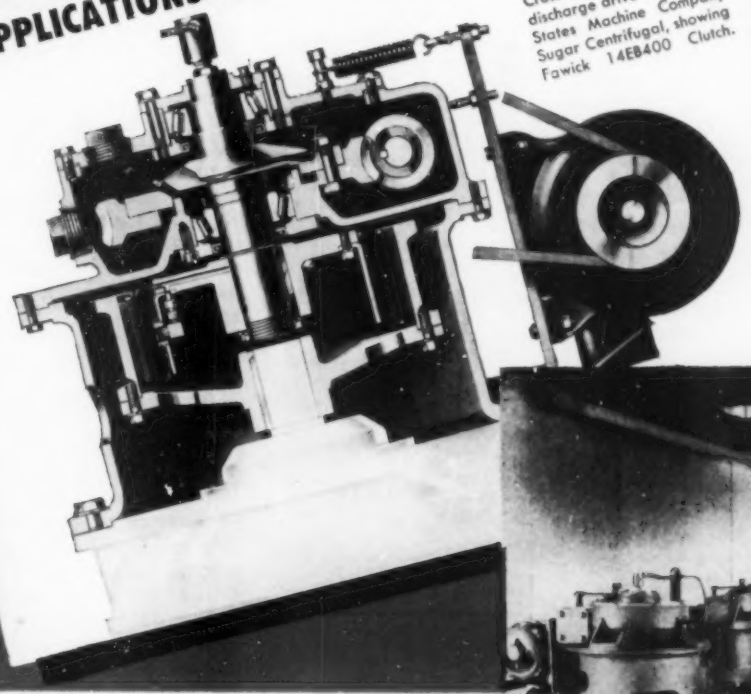
We would like you to send us, as much information from your catalog files as you deem fit, bearing in mind that our products are test equipments of all types. We custom build this equipment so that we tend to cover many fields.

We are in the process of expansion. Our new service will include a considerable amount of consultant work. So that, you can readily see a complete catalog file is of utmost importance.

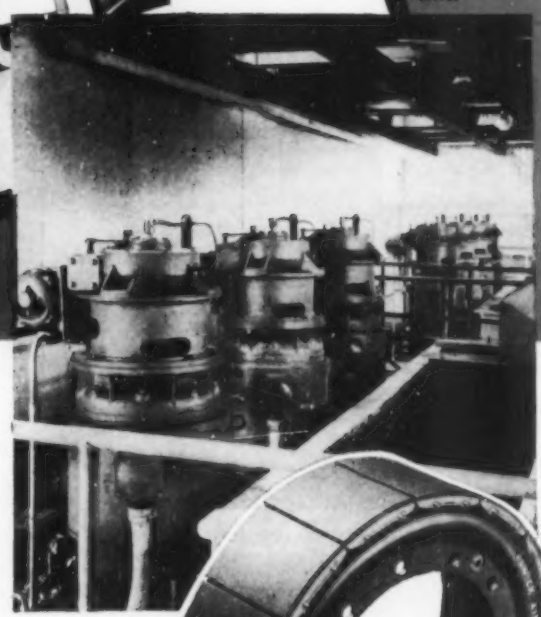
Anything you can do for us in this matter will be appreciated, and needless to say any charge on this will be met by us. —R. RYALL
Radionic Research
Montreal, P. Q.

Ed—I'm very sorry to hear of your recent misfortune which resulted in the destruction of all your reference

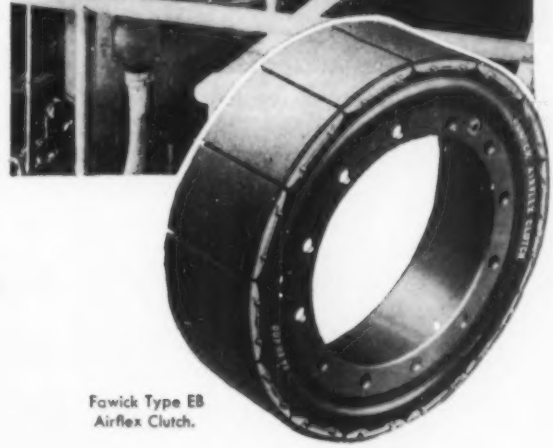
TYPICAL EXAMPLE OF FAWICK CLUTCH APPLICATIONS IN THE SUGAR INDUSTRY



Cross section of slow speed discharge drive of Western States Machine Company Sugar Centrifugal, showing Fawick 14EB400 Clutch.



Battery of 7 Centrifugals showing "Turn-fork" slow speed discharge drive.



Fawick Type EB Airflex Clutch.

In choosing a clutch for the slow speed discharge drive of their Sugar Centrifugal, the Western States Machine Company chose FAWICK because of its adaptability to the compact design required for the drive. The self-adjusting, maintenance-free FAWICK UNIT makes it possible for the clutch to be mounted in a location where repetitive servicing and lubrication would be difficult.

This slow speed drive of the Centrifugal is used in plowing the sugar from the basket after the fluid has been removed by centrifugal separation. The complete disengagement characteristic of the FAWICK CLUTCH insures the dependable free-running of the main drive motor and basket during the spinning cycle. You too will find in FAWICK UNITS the reliable, performance-proved characteristics needed in your machine operation.

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data. Naturally we'd be glad to do anything in our power to help you out.

To start with, I'm enclosing copies of our editorial index for the past several years. Unfortunately, we haven't tear sheets of all the articles listed—in fact, very few tear sheets exist for your issues prior to the beginning of 1951. It may be however, that you can refer to volumes of PRODUCT ENGINEERING in the Montreal Library and pick out the articles in which you're particularly interested. We could then make photostats for you at a cost of forty cents per page. I'm also enclosing a copy of our latest compilation of design work sheets, which I think you'll find useful. Unfortunately, earlier editions of this book are out of stock.

More On Silicon Monoxide

To the Editor:

I note in the May issue of PRODUCT ENGINEERING that information is desired regarding the source of Silicon Monoxide, and that in the Editor's note he has referred to our Company as a possible source of information.

As far as we know, there is a rather limited application for Silicon Monoxide, and the only source of supply, or at least the only people we know that have made any Silicon Monoxide is the Union Carbide & Carbon Research Labs at Niagara Falls, N. Y. We would refer you to an article in the Journal of Electrochemical Society, Volume 95, Number 6, June 1949 issue, page 316, entitled "Preparation and Properties of Silicon Monoxide" by H. DeWet Erasmus and J. A. Person.

—F. J. TONE, VICE-PRES.
The Carborundum Co.

To the Editor:

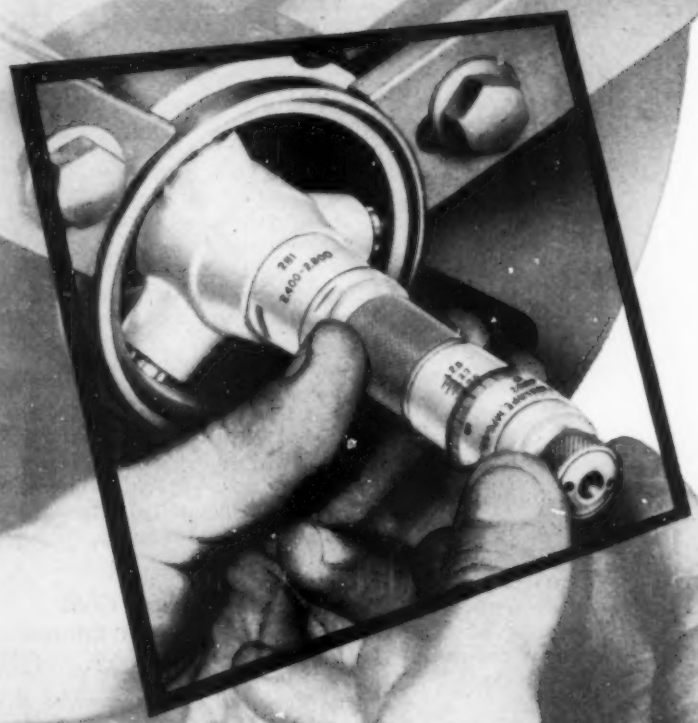
In "Our Readers Say" column for the May 1952 issue of PRODUCT ENGINEERING you published a letter by Mr. Julian Pinto of Northrop Aircraft, Inc. He mentions the need for a source of Silicon Monoxide, which he uses to coat aluminum front surface mirrors in a vacuum. Perhaps a study of the following paper, or further questioning of its author, would help solve Mr. Pinto's problem: "Preparation, Structure, and Application of Thin Films of Silicon Monoxide and Titanium Dioxide," by George Hass, Engineer Research and Development Laboratories, Fort Belvoir, Va. Published December 1, 1950, Vol. 33, No. 12, Journal of the American Ceramic Society.

JULIUS SOLED,
Asbury Park, N. J.

NEW INTRIMIK

Internal Tri-point Micrometer

Measures **any** Size Bore or Hole within range of tool... ***without masters***



Now you can realize new economies and speed by measuring bores and holes *directly!* The new Brown & Sharpe Intrimik Internal Tri-point Micrometer gives you a handy means of measuring in increments of .0001" on bore sizes from .275" to .500", and in increments of .0002" on bore sizes from .500" to 4.000". It's a big time and money saver... eliminates the need for expensive plugs and setting rings. Every feature for convenience, precision, and long service life is incorporated in its design and construction. Write for new illustrated Bulletin. Brown & Sharpe Mfg. Co., Providence 1, R. I., U.S.A.

Extensions are available for all size Intrimiks to facilitate measuring deep holes.

Furnished as individual tools and in sets

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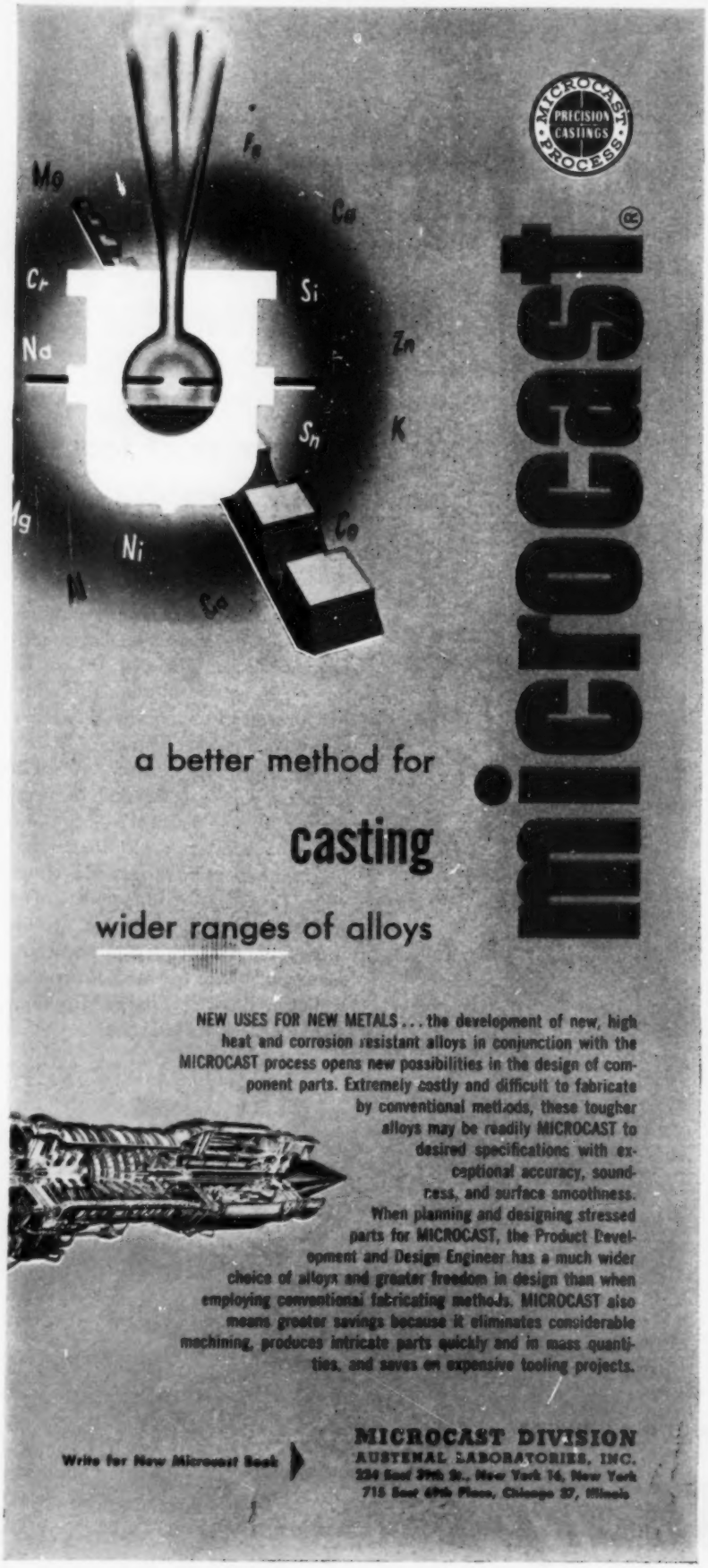
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NEW BOOKS

Strength of Materials

JOHN W. BRENEMAN, *Professor of Engineering Mechanics, The Pennsylvania State College,* 140 *pp,* 6 x 9 *in. Published by McGraw-Hill Book Co., Inc.* 330 *West* 42 *St., New York* 36, *N. Y.* $3.

This second edition provides an elementary text on the subject of strength of materials without requiring the use of mathematics beyond the level of trigonometry. The text is well adapted for technical institute courses, the correspondence or home-study field, industrial training, and armed forces courses. The book has been thoroughly tested in the Pennsylvania State Extension Division courses.

Old material has been revised by rewriting parts of the text to provide greater clarity and continuity. Many of the revisions have been suggested by users of the first edition. The chapter on the properties of engineering materials has been deleted because of the rapidly changing information in this field; instead, the essential information has been included in tabular form. The author has introduced the study of deformation in shafts, and the study of beam deflections has been enlarged to include a wider variety of loadings. Other topics covered include: simple stresses, riveted and welded connections, stresses in thin-walled cylinders, torsion, beams, and columns.

National Electrical Code Handbook; Seventh Edition

ARTHUR L. ABBOTT, 652 *pp,* 5 x 7½ *in. Published by McGraw-Hill Book Co.,* 330 *West* 42 *St., New York* 36, *N. Y.,* $6.

The Seventh Edition of this standard handbook tells how to handle all types of wiring and installation jobs in strict accordance with the latest National Electric Code. Completely revised, it includes all changes, new rules, etc., given in the 1951 National Electric Code. It explains rules and measurements for all jobs—what they mean—how to apply them. With it, the reader can refer to any point quickly by means of the key on the front cover and flyleaf and have the assurance that no rule which relates to the subject has been overlooked. Planned for quick reference use by busy, practical men, the handbook can

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be used also by anyone who wishes to make a thorough study of the Code.

This book enables the reader to grasp readily the general plan, scope, and purpose of the National Electric Code requirements. It makes the practical application of the rules clear and easily understandable. In the Handbook you can look up the Code definitions; descriptions of each of the 15 types of wiring recognized by the Code for use in light and power wiring systems; the rules for the installation of the commonly used materials and apparatus for any standard wiring installation; and the general requirements for services, grounding, automatic overcurrent protection, and wiring installation design.

Handbook of Engineering Fundamentals

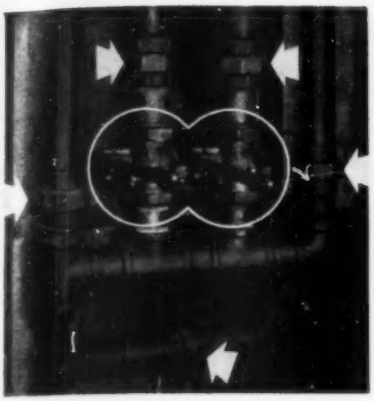
OVID W. ESHBACH; *Second Edition; 6 x 9 in. John Wiley & Sons, Inc., New York, N. Y.*, $10.00.

The first edition of Esbach's Handbook was well received by the engineering entirety, primarily because it contained in compact form a great deal of the fundamental engineering data required for design, development and production. This, the second edition, has been considerably revised insofar as subject matter is concerned, but still contains basically the same type of data.

The section headings listed in the Table of Contents are as follows:

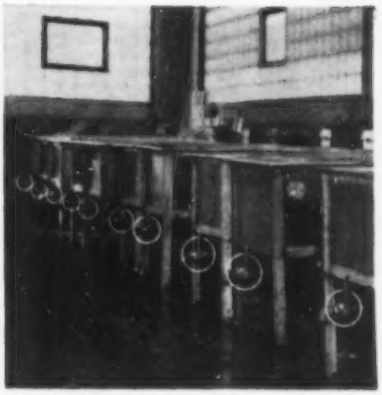
Section 1. Mathematical and Physical Tables
Section 2. Mathematics
Section 3. Physical Units and Standards
Section 4. Mechanics of Rigid Bodies
Section 5. Mechanics of Deformable Bodies
Section 6. Mechanics of Incompressible Fluids
Section 7. Aerodynamics
Section 8. Engineering Thermodynamics
Section 9. Electricity and Magnetism
Section 10. Radiation, Light, and Acoustics
Section 11. Chemistriy
Section 12. Metallic Materials
Section 13. Non-Metallic Materials
Section 14. Engineering Law

As in the previous edition, there is very little exposition in the current edition. The data is presented in very concise, staccato form. Changes that have been made are as follows: (1) Engineering tables have been enlarged to include additional data on aluminum and mathematical information on tan-



Revere Copper and Brass Co. Application: On quenching lines bringing unfiltered river water to annealing furnace at 100 psi — operated 60 times daily. *Report: Rockwood Ball Valves have lasted four times longer than any other valve.*

Iroquois China Co. Application: Handling a clay and water mixture — operated 40 times daily. *Report: Each Rockwood Ball Valve has performed better, operated easier and lasted longer than any other valve this company has ever used.*



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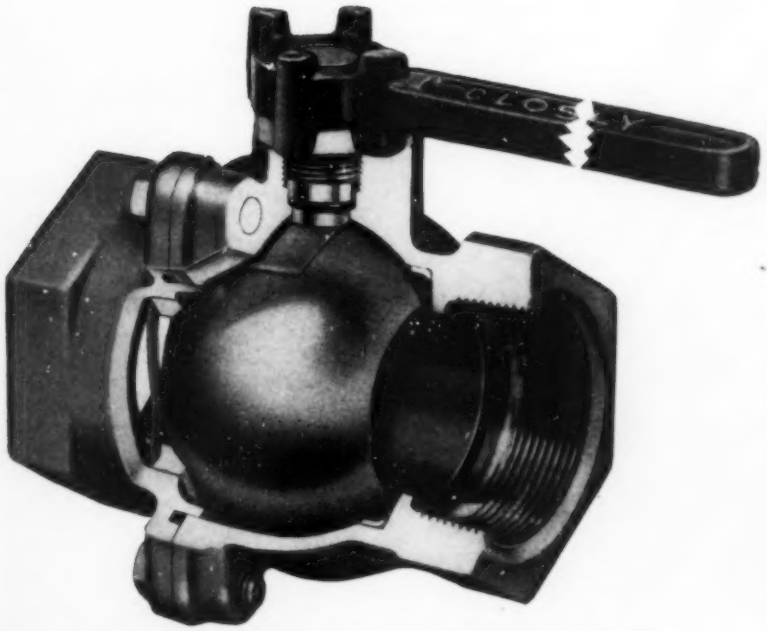

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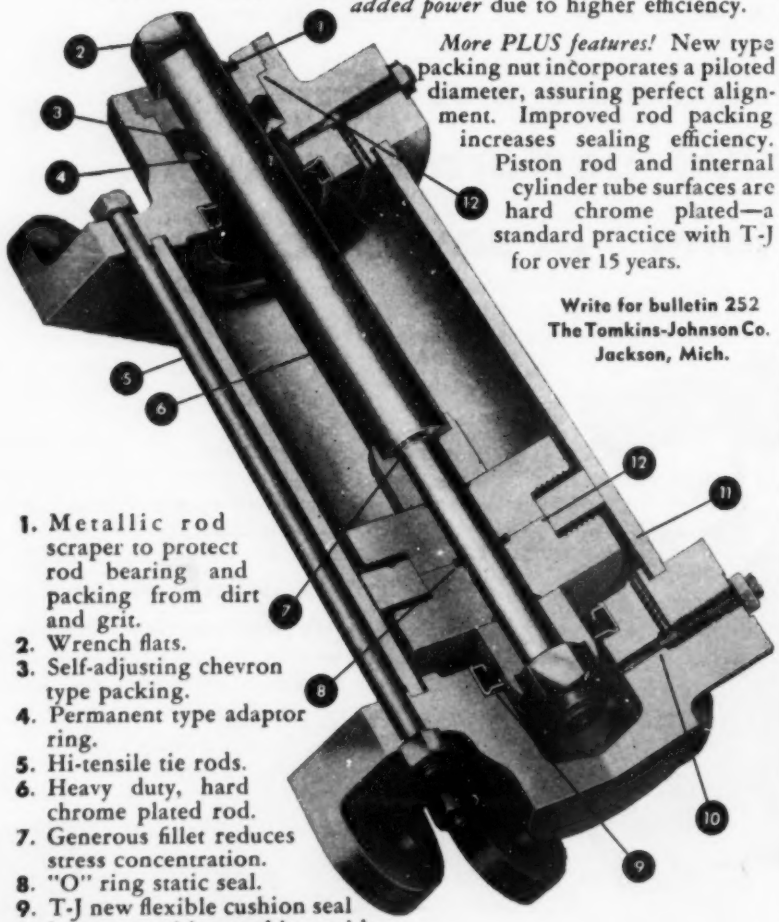

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gents and offsets angles for the civil engineer. Standards and symbols have been brought up to date and the MKS system of units have been incorporated. (2) The treatment of mathematics has been revised, with the deletion of more common items and the addition of data on statistics, determinants and vector analysis. (3) In the section on theoretical and applied mechanics a brief discussion on more generalized theory has been added on statics, kinetic and frictional phenomena. Codes of practice have been brought up to date. (4) The section on fluid mechanics has been divided into incompressible fluids and aerodynamics, and completely rewritten. The treatment of thermodynamics has been completely revised with additional illustrations and tables. (5) The section of electricity and magnetism has completely revised. (6) The engineering materials sections have been brought up to date and rewritten where necessary, and some detailed information of value only to special groups has been eliminated. (7) The section on engineering law has been re-written.

As with the previous edition, many of the sections have been prepared by specialists in industry and universities.

Advanced Calculus

WILFRED KAJLAN, *Associate Professor of Mathematics, University of Michigan, 679 pp, 6 x 9 in. Published by Addison-Wesley Press, Inc., Cambridge 42, Mass.,* $8.50.

Students using this book as a text should have a background of freshman and sophomore courses in algebra, analytic geometry and calculus. While the introductory chapters provide a concise review of these subjects, they are intended for a reference and not for inclusion in the one year course which this book covers.

The subject matter of the book includes all the topics usually to be found in texts on advanced calculus. However, there is more than the usual emphasis on applications and on physical motivation. Vectors are introduced at the outset and serve at many points to indicate the intrinsic geometrical and physical significance of mathematical relations. Numerical methods of integration and of solving differential equations are emphasized, both because of their practical value and because of the insight they give into the limit process.

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few of the finer points concerning the real number system (the Heine-Boul theorem, Weierstrass-Bolzano theorm, and related notions) are omitted. The theorems whose proofs depend on these tools are stated without proof, with references to more advanced treatises.

A large number of problems, with answers, are distributed throughout the text. They include simple exercises of the "drill" type and more elaborate ones planned to stimulate critical reading. Some of the finer points of the theory are relegated to the problems, with hints given where appropriate.

References to the literature are given and each chapter concludes with a list of books for supplementary reading.

Du Pont, The Autobiography Of an American Enterprise

E. I. Du Pont de Nemours & Company, Wilmington, Delaware, 9 x 12 *in. Distributed by Charles Scribner's Sons, New York, N. Y.*

This book presents the history of the Du Pont de Nemours company in an entertaining personal style. It is profusely illustrated in both black and white and in color to pictorially cover the period from 1800 to the present day. The history of the Du Pont company is correlated closely with the history of the United States to give the story added interest.

Prepared in connection with Du Pont's 150th anniversary on July 18, 1952 it traces the company's role in the growth and development of the nation. Pictures and text sketch the broad United States social and economic patterns of the last century and a half, underscoring the company's advance to satisfy the country's expanding needs.

Electric Circuits and Machines

EUGENE C. LISTER, *Second Edition,* 427 *pp,* 6 x 9 *in. Published by McGraw-Hill Book Co.,* 330 *West* 42 *St., New York* 36, *N. Y.,* $5.50.

This new edition of this clearly written and instructive manual gives the reader a concise, over-all picture of the electrical field and covers the fundamentals of both direct and alternating current circuits and machinery.

This book is for the person who wants a broad understanding of the electrical field without having to spend hours pouring over involved theory and calculations. Basic principles are expounded with as few mathematical explanations as possible. The author

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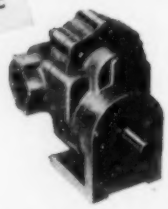

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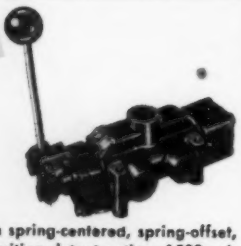

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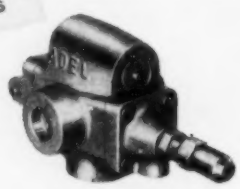

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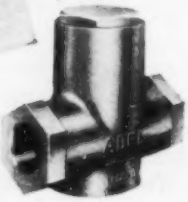

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has placed emphasis on principles and physical action rather than on a detailed analysis of theory.

Simple, direct explanations guide the reader through the intricacies of circuits, batteries, magnetism, induction, generators, various kinds of motors and controls, transformers, alternators, electrical instruments and electronic tubes. Special features of the book are the treatment of a-c machines and a section on the effective use of industrial symbols.

Fundamentals are explained by many illustrations and diagrams and by pictures of modern electrical equipment. In this new edition, illustrations have been brought up to date and wiring diagrams have been revised to conform with the latest ASA standards.

New material includes a section on Feeder Voltage Regulations and a chapter called "Circuit Protective and Switching Equipment." A discussion of complex quantity notation for vector representation has been added.

Electronic Measurements

FREDERICK EMMONS TERMAN, *Dean of the School of Engineering, and* JOSEPH MAYO PETTIT, *Associate Professor of Electrical Engineering, both of Stanford University,* 707 *pp,* 6 x 9 *in. Published by McGraw-Hill Book Co.,* 330 *West* 42 *St., New York* 36, *N. Y.,* $10.

In this successor volume to Professor Terman's "Measurements in Radio Engineering," the revision is so extensive and the scope so broadened that it is virtually a new book. The present volume covers measurement fundamentals in many fields beyond conventional radio, including television, radar and other pulsed systems, microwave techniques, and a diversity of techniques of value to the engineer in other areas.

The book features well-illustrated descriptive material on the important fundamentals of the various measurements, together with appropriate practical details and complete bibliographical footnotes. These footnotes provide an exceptionally complete coverage of the literature of the subjects treated. Thus for the practicing engineer, the book can serve as a complete and up-to-date handbook. At the same time, it is written to provide textbook material on the topics covered.

A change of emphasis is introduced in the new volume due to the fact that at the time of the earlier volume it was necessary for engineers to build their own measuring equipment, whereas today a wealth of commercially manufactured apparatus is available.

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